THE

ECONOMY

OF A

COAL-FIELD:

AN EXPOSITION OF THE OBJECTS OF THE GEOLOGICAL AND POLYTECHNIC SOCIETY OF THE WEST RIDING OF YORKSHIRE, AND OF THE BEST MEANS OF ATTAINING THEM.

BY

1796 – 1855

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LECTURE.

Mr. Chairman and Gentlemen,

I regret that the exposition I have been requested to make, of the objects contemplated by the Geological and Polytechnic Society of the West Riding of Yorkshire, has not fallen into abler hands—I regret especially that it has not been confided to one more conversant with the mineral resources, the natural productions, and the manufactures of this important district. So far as my knowledge extends however, I cheerfully enter upon the subject, trusting that you will overlook any omissions, which a longer residence in the county might have enabled me to avoid.

The two leading objects which you have in view, and which are expressed by the title of your Society, have been already so well stated in the prospectus which I now hold in my hand, and which has been circulated among you by your Secretary, that all I shall have to say will be little more than an expansion of the ideas which it suggests.

In considering the mutual relation of the different branches of knowledge, there are certain aspects in which Geology connects itself with en[illegible] which at first sight appear remote from its proper [illegible]—not with the sources of national wealth merely, but [illegible] the causes also of national manners and morals.

In surveying or passing over the surface of an inhabited country—seeing it spotted with towns—sprinkled with villages and hamlets—here exhibiting a busy and crowded population—there a thinly-peopled and rural district—enveloped in some

places in almost impenetrable smoke—in others gilded and glittering in the bright sunshine—ringing in this spot with the din of countless hammers—in that reposing in almost unbroken silence—we seldom think how much of all this variety depends on the dead earth itself—on the nature of the rocks we are treading beneath our feet.

And yet upon reflection there are few things more striking, than the close connection which exists between the number of inhabitants in a district, and the nature not of the soil alone—for I speak not of agriculture—but of the solid rocks on which the soil itself rests, and to which in very many cases its fertility is owing.

Cast your eyes over the face of Europe—see where the great masses of men are collected together—and ask what circumstances have drawn them into these spots. Metropolitan cities must be excluded: the seats of great governments, the residences of courts, possess peculiar attractions, independent of the causes we are now considering.

In parts of Silesia, in Rhenish Prussia, in Belgium, in parts of France, in the Western States of North America, in parts of Peru, and on many other spots of less extent, we observe the population clustered like bees and gradually thinning, as we recede from these centres. Fertility of soil is not the cause of this appearance, nor are there great capitals or sea-ports on those sites—they have this only in common, that the bowels of the earth beneath them contain rich stores—which the research of man has brought to light, and his ingenuity has taught him to appropriate.

But come to Great Britain, and see on what spots among ourselves the densest population is to be found. Glasgow, Newcastle, Leeds and Sheffield, Manchester and Liverpool, Birmingham, and Wolverhampton, are severally the centres of crowded and laborious races of men. And how are these men employed—what feeds them—why do they so throng and jostle each other in these comparatively narrow districts,

while abundant space exists, and purer air, in other parts of the country?

Look at this geological map, and you will see that all these towns are seated in the centre of great deposits of coal. You will also understand how all this busy population is fully employed—either in raising the fuel from its native bed, or in those processes of art which the proximity and cheapness of combustible material enables them to execute with the hope of profit. Manufacturing industry in those districts is born of mineral treasures, and by them it is sustained and encouraged.

Now if disease prevail and pestilence find its most easy victims—if immorality diffuse itself, and ignorance spread her mists, most widely in our largest towns—and if these towns owe their being to certain subterranean stores; then the longevity, the morality, the intelligence, as well as the wealth of its inhabitants, must greatly depend on the geological structure and mineral contents of the district in which they live.

Is not the enquiry then—What is this structure, what the mineral contents of the district in which I live?—one of the earliest and most important which *ought* to present itself to every enlarged and thinking mind. As all the parts of the empire are bound together under a common rule and have one common interest, so all the inhabitants of a district—high and low, employer and employed—are linked together by the same common chain, fastened to the same everlasting rocks, and the best measures for the regulation and government of all must rest on the same [illegible]able basis.

Of all the districts, i[illegible]ineral riches abound, those are the most valuable, [illegible]efore the most deserving of examination, over which [illegible] extensively spread.

Value of coal deposits.—There are several aspects in which the great value of coal districts presents itself,—

1°. The immediate marketable value of the produce of a rich coal district, is almost as great as if the same extent of country produced gold or silver or diamonds, in equal abun-

dance with the richest known districts in the world. The total value of all the gold and silver raised from the mines in South America in 1800, when they were all in full activity, was estimated by Humboldt at £8,700,000. The area of England is hardly a tithe of this great mineral district; and yet the coal consumed, in England and Wales, being about 20 millions of tons, estimated at 8s. a ton, amounts to 8 millions sterling. A higher estimated value of one shilling a ton, which is still lower than the value adopted by some economists, would give us a surplus for the actual value of coal alone, exclusive of every other mineral raised in England and Wales, over the entire value of the precious metals raised in that tract of country we have been accustomed to consider the richest in the world.

2°. Again, if we consider the comparative utility of these mineral products—the employment they give or create—the importance of coal becomes strikingly manifest. The transport of the precious metals from the mine to the market is estimated to cost 2 per cent. on their value—the cost of transport nearly doubles the price of coal to the household consumer; so that the carrying trade of England and Wales, by sea and land, is benefited by the conveyance of coal to the extent of at least 5 or 6 millions a year.

But this is only a small item in the comparative utility of coal. About two-fifths of our coal is consumed in our manufactories, converting other minerals into marketable commodities; giving employment t[illegible]s of men, and enabling them to enhance the value o[illegible]erials a thousand times, by adding to them the price [illegible] own ingenuity and industry.

3°. Consider further the nature of the surface of our coal fields, compared with that of countries rich in gold or silver, or precious stones. We should unwillingly exchange our fertile fields, rich in corn and pasture, with their round and undulating hills and varied scenery, for the dreary ridges of

the Cordilleras, or the golden sands of Brazil, of Hungary, or the Ural. Our minerals are stored beneath, while agriculture is still rewarded for her surface toil. We are doubly rich; at once in stores of mineral treasure, and in the exhaustless fertility of the soil which covers them.

4°. Nor are these all the beneficial aspects in which the possession of stores of coal presents itself. Why are the forests so extensive in Russia, Norway, Sweden, and parts of Germany, as to cover nearly one-third of the surface? Is it that the population is thin, and that the land is waste for want of cultivators? Then why in Austria and Prussia should one-fourth be under wood—in Belgium one-fifth? The reason is obvious. Fuel is as necessary as corn for the support of life in those northern regions, and by a limited supply of the former, agriculture and population are equally arrested. When coal is wanting, wood must be grown for fuel; and forests must spread themselves where corn might ripen abundantly and cattle graze.

In our climate were we destitute of coal, upwards of one-fourth of the surface of our island would be required for the growth of fuel for domestic purposes, even supposing the population much less dense than it now is. Large tracts of land must in that case be withdrawn from cultivation, merely for the support of life. And if manufactories, as in Sweden and Russia, had to be fed by similar fuel, still more land must be thrown into forests—and it is almost certain that were the whole surface covered with wood, it would not produce an amount of combustible material equivalent to the 20 millions of tons of coal supposed to be raised at the present time in England and Wales.*

* The United Kingdom contains about 57 millions of acres, of which about 2 are covered with wood. France contains about 114 millions of acres, of which about 16 are covered with wood. The coal raised in France in 1836 (30 millions of quintals), is equivalent to the produce of 27 millions of acres of wood, supposing it fit for cutting every 16 years.

What an advantage then do nations derive from the possession of deposits of mineral coal? They not only add to their wealth, their strength, their population, their comforts, their resources, but they are actually equivalent to an increase of territory, and large as this country is, its coal measures give it an importance equal to twice its area, and enable it to support at least a two-fold population.

Objects of the Society.—The Geological and Polytechnic Society of the West Riding proposes to study the nature, extent, and availableness of your mineral treasures—to enquire how they may be best and most economically obtained—how when obtained they may be most profitably employed—how the manufactories which depend upon or are engaged in working up your local products may be improved—how lessor and lessee—employer and employed may be equally benefited by the bounties which nature has so impartially scattered around you.

The proper objects of a local Society should be regulated in some measure by the position, the resources, and the industry of the district in which it is placed. Your resources and industry are all more or less dependent on your beds of coal and ironstone—in the remarks I have to make, therefore, on the main objects of your Society, I shall confine myself chiefly to topics connected with these two staple productions.

Extent of your coal-field.—Your coal-field may be considered as composed of two parts—that which is *known*, and that which is *unknown*. Towards the north, the west, and perhaps towards the south, the [illegible] limits of the workable beds are tolerably well understood. Towards the east lies a vast tract of country still unexplored, and of which the mineral riches that may hereafter be made available, are consequently unknown.

In regard to the *known* there are several points both of theoretical and of practical interest on which your Society will be enabled to throw light.

1°. The *identity of beds*, and the mode of identifying them —in the various parts of this field—and with the beds in other, as in the Lancashire coal-field. Are the beds invariable in thickness, in quality, in relative distance, or if in none of these, are they characterised by peculiar fossils, animal or vegetable? Is the nature of the roof, of the floor, or of any neighbouring bed constant, is the quantity or quality of the water it contains peculiar to any stratum, or is it possible by any other criterion to distinguish from each other the several members of the coal series? Such information will be useful not only to scientific men, but to all parties having a pecuniary interest in the coal measures. It will remove a portion of that obscurity which rests on the relations of the strata, and the consequent risk of loss in sinking through them. Why should it be that the instant a mine is sunk and the coal reached, the value of the mineral should increase nearly ten fold? Were the floating knowledge of those conversant with the several districts collected and embodied, such things would be impossible, and the mining for coal, being based on well ascertained data, instead of being an uncertain or adventurous speculation, would become one of the safest and surest ways to riches.*

2°. The same remarks apply to the *disturbances and dislocations* which traverse the coal-field, in different directions. You are all aware how much these affect the value of the coal beds—and how important it is to know their position—in what way they throw the beds up or down, and how they affect their quality or the general dip. Almost every coal-owner or viewer is in possession of the direction of those dislocations which occur in his own locality, and of their effects

* QUERIES.—Number—relative position—distances—thickness—quality—*peculiar characters* of the several beds—nature of the roof. Do the quality and thickness vary in different parts of the field? Do any of the seams part into two or more? From what line does the parting commence—at what rate does it proceed, and what effect has it on the coal?

on the relative positions of the strata—and few persons possessed of real knowledge will desire to conceal from you the information they possess. Let the Society embody all these local observations, and connect them on one map of the district, let them publish extended sections such as those given by Mr. Buddle, of the Newcastle coal-field, and they will not only render a service to the county, to the land-owner, and to the lessee, but they will add to our knowledge of an interesting department of physical geology, and entitle themselves to the thanks of scientific men.

And what can be more interesting than to study those great dislocations and *heaves* which the strata seem to have undergone in this county, as illustrated by the remarkable paper of Mr. Hartop read at your last meeting, and to consider how tremendous must have been the convulsions, of which in former epochs this district has been the site,—by which the solid rocks seem to have been not only tossed up and down, but actually shifted laterally many miles out of their original position?

3°. Of equal interest is the supposed connection between the Lancashire and West Riding coal-fields. A careful collation of the observations in each field would well repay the labour bestowed upon it; and I hope some member of this Society, of whom several are well acquainted with both fields, will be found willing to institute this comparison. Observations made in the one field, should they prove to have been once united, would throw light on the contents of the other, and what you publish here would not only benefit your own county but that of Lancashire [illegible]. And thus it is, that general and national good springs out of the zealous and united exertions of local societies, instituted for special and local purposes.

To the general geologist the mutual relations of coal-fields still further asunder possess much interest. Between those of Yorkshire and Durham, for example, is there any other

connection than that of nearly equal age? Some coal-viewers from the latter county have pronounced the low main of the Garforth and Manston collieries to be the Hutton seam of the Wear—so much are they alike in geological position, in thickness, in quality,* in the several layers of which they are made up, and in the partings by which these layers are separated. Is this similarity accidental only?

4°. *Trap dykes.*—In the known part of your coal-field no trap dykes have been yet, I believe, observed; should they be met with hereafter, there are many important questions connected with their appearance, their direction, and their effects on the strata, to which, from their practical as well as theoretical bearings, you will feel inclined to give an attentive consideration.†

* At Middleton it is believed that the seams worked there are the same as those of Garforth, and that the low main at the latter place is the Beeston. At Garforth again it is said that the seams known by the name of the *hard band* and bright *coal* of 5 and 6 feet in thickness respectively are the Middleton seams, and that the *low seam* 10 feet in all or 5 feet clean coal is 100 yards below them. The quality of this latter seam has hitherto been much inferior to the Hutton seam, but it is said to have recently improved very much towards the dip.

† In regard to dykes, it may be enquired,—what strata do they pass through? Does the red sand or magnesian limestone appear to arrest them? Do they run parallel or do they incline to each other, and at what angles? Do they come to the surface in perfect walls, or do they spread out into plates or masses, either overlying or interlying? Where they come to day, do they form ridges as along the Roman wall in Northumberland, or do they flow extensively over the surface, as in Fifeshire, or form large craggy isolated rocks, as at the Calton Hill and the Castle Hills of Edinburgh and Stirling? Where interposed, do they form one large sheet only like the whin sill of the North of England, or several perfectly distinct sheets as in Derbyshire—or do they thrust out between the beds long finger-like masses, as in the Staffordshire coal-field? What is their action, mechanical or chemical, on the coal itself?

In all our coal-fields some obscurity exists in regard to the position, direction, and extent of the trap rocks and dykes. In the county of Durham, long as it has been worked, much is still imperfectly known. In the immediate neighbourhood of the city of Durham, for example, instead of one dyke running from the Tees by Witton-le-Wear to Hett and Quarrington Hill, turning in its course northward to Butterby, as it is represented on some of the maps—there are in reality two dykes running parallel to each other at an interval of nearly a mile. The magnetic bearing of the one dyke at Hett is west 5° to 9° north; that of

Part of your coal-field again is unexplored and *unknown*. This unknown portion consists of two parts, that which lies within the limits of the field actually worked, and that which stretches towards the east, where no sinkings have yet been made.

1°. In the centre of a coal-field, especially where few disturbances occur, the relative position of the several seams is ascertained with comparative ease, and is known with tolerable accuracy. But towards the extremities or near great faults, the position of beds, even such as may be worked, in relation to others well known in the district, long remains doubtful. In this state, for example, are the seams now working at Middleton, Lofthouse, and Haigh Moor. It is a question yet undecided whether the main coal in these three localities be the same or different beds. They differ in quality and thickness, but so does the same bed in different parts of its extent; and the prevailing opinion has hitherto been, that the coal at these places has the same geological position. There are reasons for believing, however, that the Middleton beds occupy a lower position; and consequently that in the Haigh Moor and Lofthouse districts the important deposits now mined for at the former place are yet untouched at the latter, and will form an invaluable resource when the coal at present working has been exhausted.

Similar observations will apply to other districts; and thus a general identification of the strata,—or the discovery of characters, fossil or mineralogical, by which they may be readily identified,—will not only enable you to form a more correct idea of the value of the minerals in any given locality, but may reveal to you the presence of mineral riches of which the very existence had previously been unsuspected.

the other, the more northerly, at Butterby, is west 7° to 9° north. The former can be traced for many miles; the latter has not been observed coming to day, except at Butterby, where it crosses the river Wear at two places and may be traced across the Peninsula, and for a short distance on either bank.

Again. How far does your coal-field extend towards the east? Does it stretch to any distance beneath your red sandstone? Has it any narrower limit than the eastern shore of the island? This question can only be solved by trials. And it is one which, under the auspices of your Society, we may hope to see answered more or less satisfactorily. It is an object worthy of your attention to select a spot far to the east of any known workings, and to bore or sink at the expence of a common fund. The discovery of extended deposits would not enrich individuals more than it would add to the prosperity and resources of the district.

Such obscurities are common to your coal-field with almost every other in our island. That of Staffordshire is bounded by newer rocks, beneath which the coal measures are known to dip. What new and abundant supplies may be looked for when the red rocks are perforated and widely explored? How far the coal strata of the county of Durham extend toward the south is an important problem, of which we are as yet unable to give a *satisfactory* solution. There are probably many square miles of coal between the Wear and the Tees destined to reward the labours of future years, when the more accessible portions now working are in some measure exhausted.* Are the coal beds of Lancashire to be sought for beneath the red sandstone of Liverpool, or those of Whitehaven and Maryport, beneath that of Carlisle or of Dumfries? To the south-east of the Glasgow coal-field, beyond the limits within which pits have hitherto been sunk, extends a tract of red sandstone, comprising an area of 32 square miles. Beneath this sandstone, at Hamilton, coal has been met with at a depth of 70 or 80 fathoms. Under how much

* The coal rises to the south at Eldon and other collieries in that neighbourhood, and is said to come out under the limestone. May there not be a break such as that which separates the Stourbridge and Bilston sections of the Staffordshire coal-field? At all events there is much unexplored ground in the direction of Hartlepool.

of this tract does the coal exist?—how many square miles of unexplored country may hereafter be added to the known area of this important mineral district? A glance at this geological map will show you other localities, in Scotland, in England, and in Wales, over which sufficient obscurity rests to give ground for hope that the real extent of our mineral riches is far from being known, and that ample rewards await the mining adventurer in places yet untried,—where the presence of workable coal-beds has hitherto been unthought of.

But if found far to the east of your present workings in Yorkshire, the coal must necessarily be at a greater depth. And here another question presents itself, and another field opens for the exertions of your Society—From what depth can coal be raised? At Monkwearmouth colliery it is brought up from a depth of about 1600 feet, and this is by no means the utmost limit from which it may be safely raised by a single lift. And as we are not restricted to a single lift, there can be no insurmountable obstacle to the mere lifting up of the coal from almost any depth. It may be raised by successive lifts and underground engines, to successive stages, and thus conveyed to the surface easily, safely, and at no great additional cost. When circumstances render it necessary, it will come within your province to discuss how this may be best effected and at the least expence.

Internal heat.—Yet, supposing the coal to be actually met with at these great depths; and supposing the mechanical difficulty in raising it to be overcome, another obstacle of a serious kind presents itself, to which I shall shortly draw your attention.

It is a fact established apparently beyond question, that from a depth of about 100 feet beneath the surface of the earth, the temperature gradually increases as we descend; and, according to a law differing slightly in different localities, yet as far as observations extend, constant in the same locality. On an average this increase is about 1° (Fahrenheit) for every 50 feet.

This rising of the temperature as we descend is a fact of great interest in the present state of our knowledge, bearing as it does on the question of the earth's heat. To make and classify observations on this subject in your numerous mines and borings, and to deduce the law of increase in this large district will be another object which, as a Society, you will, I hope, find leisure to undertake. And this you will be stimulated to do, not merely because of the theoretical interest attached to the inquiry, but because of its practical bearing on the working of deep mines.

In Monkwearmouth colliery, sunk now to a depth of 270 fathoms (1620 feet), the temperature is constant at about 76° (Fah.), and considerable distress is felt by the workmen in consequence.*

Suppose rich coal to lie at still greater depths, and suppose it accessible, there is a risk of the temperature being too high for working it, or from the diminished energy of the collier in so warm an atmosphere, of working it to profit.

At a depth of 400 fathoms the temperature in Yorkshire would be about 96° (Fah.) In such an atmosphere we cannot demand from the workman the same amount of labour he is now able to give, or for an equal length of time. Yet you are not to consider this as a depth either unattainable or unthought of. A shaft is about to be sunk on the shore at Whitehaven, under the skilful direction of Mr. Peile, to a depth of 300 fathoms, for the purpose of bringing out by a level the coals which dip under the sea. Do you suppose that 20 years hence the enterprise of man will not lead him hundreds of fathoms deeper, if the hopes of gain lie before him, and no law of nature prohibit his descent?

This question, therefore, which to the geologist presents itself as a purely theoretical one, must assume in your eyes an important economical aspect.†

* In the workings it is said to rise, probably in the less perfectly ventilated parts, as high as 80° (F.)

† In regard to internal temperature, Professor Phillips has circulated the

But other methods of working coal seams may be devised when the necessity arises. Where the arms of man become feeble, the force of an engine will remain unimpaired; and some of you whom I now address may live to discuss in this Society the most efficient means of applying machinery to the excavation of coal. The prospect of possible, nay of assured, difficulties must not damp your ardour, or prevent you from pushing forward your observations and discoveries in every direction. Difficulties retard the advance of general knowledge only for a time—a new instrument falls in our way, or an intellectual giant arises—and the advance becomes easy and rapid.

Waste of coal.—In connection with the supply of coal there is another topic not unworthy of your attention. Coal mines in this country are worked not for the national good but for individual profit, and generally with a view to the *greatest profit in the shortest time.* The immediate interest both of the lessor and the lessee, but especially of the latter, whose interest ceases after a term of years, has too often been at variance with the true interests of the nation. It is right and proper that the greatest possible profit should be aimed at, but it should be with the least possible waste. I need not remind you how much of the precious combustible is wasted in some of our coal-fields—how much is broken to powder, needlessly as some think, in hewing it out—how much is left behind in the mine—how much is actually burned or other-

following queries:—Elevation of the surface above the sea in feet—mean annual temperature of the air at the surface—mean temperature of permanent springs issuing from rock. Temperature on the day of observation, 1°. Of air in the shade 4 feet above the ground. 2°. In the mine near the base of the cold air shaft. 3°. In subterranean spring, if constant. 4°. In a hole of the rock three feet deep. The depth from the surface—and the quality of the springs and nature of the rocks in which the temperatures are observed should also be noted. This subject has frequently occupied the attention of the British Association, which has set apart a sum of money for supplying thermometers to such persons as may be willing to make observations. These thermometers may be

wise wasted at the surface. In working the best seams in a district also, sufficient care is not always taken to preserve uninjured higher* and less valuable seams, which at a future day may afford an ample return to the miner. You will entitle yourselves to the thanks of the nation at large if you should succeed in diminishing any of these causes of waste. Local Societies, enrolling among their members as this does, so many practical men, have very much in their power.†

I do not press upon you these considerations because I think your known supply of coal is likely to be soon exhausted. I believe it to be so far inexhaustible, that there is little probability of its ever being all raised. We are accustomed to enquire how long a given district will yield a given supply

obtained on application to the assistant Secretary, Professor Phillips. Observations should be made, if possible, on several adjoining strata, since it has been observed by Mr. Anderson, that in the county of Durham the temperature of the coal differs by one or two degrees from that of the shale immediately beneath it.

* According to Mr. Buddle, lower seams are sometimes so much injured by the working of those above them as to become themselves unworkable. Thus in the Wallsend colliery, the *metal* coal (2ft. 3in.) which lies 7½ to 8 fathoms below the high main coal, was so much broken and dislocated by the *creep* in the latter, that though the coal was of respectable quality, and approved in the coast markets, it could not be worked to profit.—*Transac. of the Nat. Hist. Society of Newcastle, II., p.* 316.

† Few persons are aware of the comparatively small quantity of the coal contained in a thick seam which is actually brought to market. Many even who work the coal have very indefinite ideas as to the real amount of waste. What per centage of the coal seams is ultimately left in the mine unworked—of that which is worked how much is left behind as small—of that brought to bank how much is separated by screening—of the screenings how much is sold or used, and for what purposes? The general circulation of such queries and of the answers obtained from different localities, would throw so much light on this matter and so forcibly arrest the public attention as to lead to some early remedial measures. At all events it would insure the adoption of a more uniform system, and the introduction of the more economical methods of one district in place of the more wasteful ones of another. In the Newcastle coal-field it has been estimated that "nearly one-fourth of the coals won up the shafts is taken away by screening before they are put on ship-board—by far the greater quantity of which remains in large heaps near the mouth of the pit," and ultimately takes fire spontaneously. How long must this continue?

of coal, and calculating the total thickness of the beds, and the area over which they extend, to pronounce that by a certain time the locality will be exhausted. But demand is not dependant on supply alone, the quality of the coal and the cost at which it can be raised, are the main points on which the question of demand hinges. The moment the cost of raising coal at one spot exceeds the cost of transit added to that of raising it at another spot, from that moment the former must cease not only to export but to supply the home consumption. Long before any of our coal-fields are exhausted the increased cost of working must greatly lessen the demand. And as the manufacturer will thrive best where the coal is cheapest—other things being equal—a rise in the price of coal will transfer the sites of manufacturing industry from one locality to another—leaving, in most places, a supply for local and domestic wants sufficient to last for an indefinite series of years.

The great aim then, the true interest of the coal-trade, and especially of the coal-owner in any given district, is to prevent a serious rise in the price of coal in that district, and one important means of effecting this end, is to prevent all unnecessary waste of that which is easily and cheaply accessible.

The evils which may result from the want of a due subordination of private interests and profits to the public welfare are strikingly illustrated by the present state of the coal-field of St. Etienne, in France. The manorial right is in the crown, which has been in the habit of granting leases without sufficiently strict provisions as to the mode of working the mineral. Every leaseholding company, therefore, worked their coal at the least expence to themselves, and with so little precaution, that the water which accumulated was permitted to make its way successively from one mine to another. Abandoned in succession, the mines over a great part of the coal-field were ultimately flooded from a common source. The consequence of this state of things

was, that coal rose to an extravagant price. None of the companies would be at the expence of draining their own mines, because to do so they must also drain several others. They could not agree to drain them out of a common fund; for it was impossible to fix the share of each to the general satisfaction; while in the meantime the owners of those mines which were still in operation, could not be expected to favour a project which, if successful, would deprive them of their monopoly and their enormous profits. Government, therefore, has been obliged to interfere, and the whole is to be drained at the joint expence, according to parliamentary regulation.*

Duration of coal.—From what I have stated, it will already have occurred to you that there is much fallacy in the conjectures, many of them doleful enough, which are so frequently hazarded in regard to the duration of coal. Some perceive in our national stores fuel laid up for thousands of years, even at the present increasing rate of consumption, while others pronounce as confidently that cold and starvation await our unhappy island before five centuries shall have elapsed. It is true of certain districts that in a few centuries the price of coal will be much enhanced, and they will cease in consequence to ship it in any quantity; but it cannot be true of any great coal-field that in any assignable time the supply of combustible material will be so completely exhausted that the forests and peat bogs shall become the only sources of fuel. It is probable rather, that even in such districts, coal will be long

* On the Tyne, Holywell, Backworth, Earsdon, and another new pit, are all drained by the Holywell engine. Near Bolton also there are several pits in which the porosity of the coal is such as to consign to every new colliery towards the dip, the labour of pumping out the water for those towards the rise. Should not the common draining in this case be performed at the common cost?

The legislature has thought so, for in the local canal Acts certain privileges of access to the canal are granted to collieries on the rise, only on condition that, if drained by collieries to the dip, they should pay part of the expense.

and largely imported before the domestic seams are wholly raised. From foreign countries, as from the immense deposits of the United States, we might even now import coals to the provinces, at a price, little if at all exceeding that actually paid by the London consumer—how much more cheaply may we expect to do so centuries hence, when we behold the strides which steam navigation is now making.

So far in regard to the personal comfort of future generations. Nor are our manufactures in much greater danger. The total present consumption in Great Britain and Ireland is probably* upwards of 20 millions of tons per annum, and it may hereafter rise to 30 millions. So vast a demand it is true would exhaust our known coal-fields in a calculable time, but we have the unknown in reserve, to which ingenuity and enterprise will gradually extend themselves. We have also other hopes. The present waste of coal in the mine and on the bank cannot always continue, and in the progress of art and of general knowledge, we have an assurance that every year as it increases the necessity, will also increase the means of economising our valuable resources. When we consider the augmented effect of coal in the steam engine since the days of Watt, and the saving of fuel which the introduction of the hot blast and of anthracite coal in the smelting of iron promises to occasion—we cannot doubt, that a *general* rise in the price of coal would be a national advantage, since it would stimulate ingenuity to the discovery of other improvements, by which equal effects might be produced without increase of cost. Such a stimulus is already in some measure supplied, by the economy of fuel

* How very deficient are the data on which our calculations in regard to the consumption and duration of coal in almost every district are founded! Would it be possible to obtain returns to such questions as these—Coal raised at the different mines—Seams from which it is obtained—Selling price at the mine—Quantity exported—coastwise, foreign—Average length of transport by railways, and cost of transport—Home consumption—for domestic purposes—for manufactories?

which the employment of steam vessels in long voyages renders necessary, and from this, important results must follow. Meantime, the only legitimate end to be aimed at, by speculators on the duration of coal, is the prevention of all waste. If to the best of our power we husband our resources, we may safely leave to posterity the management of their own interests,—the task of compensating for a diminution of mineral resources by an increase of mechanical skill and ingenuity.*

Workable seams.—I may here allude to another element of the present enquiry—the workable nature of seams of coal. Some of the beds which are known to exist will never repay the cost of excavating them; but of what is possible in regard to the working of coal to a profit, even at the present day, we can form no accurate opinion, from what we see taking place in the rich and favoured neighbourhoods of Newcastle and Leeds. At Wallsend, the yard coal three feet in thickness, divided by a four-inch band, and of a quality which in that district is considered inferior, cannot be worked to a profit; and in the western part of the same colliery, the Bensham seam is considered unworkable, though it contains

* Speaking of the effect of the improvement of steam-engines in Cornwall, which, in 1829, according to Mr Davies Gilbert, exceeded in duty the best engines in 1795, in the proportion of 27 to 7, Sir Charles Lemon observes,—"With respect to the effect produced in the mines by this progressive improvement of the steam-engine, two kinds of statement have been exhibited. The first, shewing cases of mines previously abandoned, but resumed with profit and effect: and the second, where the increase of power and saving of fuel have rendered profitable undertakings which, though still continued, were sinking under the pressure of their expenses, and appeared to have reached the limit to which they could penetrate.

"Mr Taylor cites many instances illustrative of each case; and it is impossible to read these without being impressed with the conviction that the prosperity of the Cornish mines has been maintained by the constantly increasing power of the steam-engine. In fact, new powers have been developed almost from year to year, as the old methods became exhausted, and the depths attainable were worked out. Were there a limit to human ingenuity, the inference from these facts would be alarming."—*Journal of the Statistical Society of London I.*, *p.* 67.

an undivided bed of good coal of 2 feet 10 inches in thickness. In the Whitehaven coal-field a seam of 2½ feet is worked, but six inches of a stone roof are removed at the same time, and 100 yards in width of the coal being cleared away at once, the roof is supported by the stone thus obtained. At Ringley, near Bolton, a seam 19 inches in thickness is worked to profit, though in a pit now sinking they calculate on having to pump up water incessantly at the rate of 700 gallons per minute: the coal is of great value from its making the best coke in the country. Near Manchester, and under it, a seam of 15 inches is worked, the roof and floor being good. The depth is about 130 yards; the workings are drained by drifts, and the coal is sold at the pit-mouth at 5s. 6d. to 6s. per ton. At Croglin a seam of 16 inches is worked, but no draining is required. Near Blackburn, in Sir Robert Peel's manor, two seams are worked, one of 13, the other of only 11½ inches in thickness. The floor is said to be as hard as flint; three inches of the roof are taken off, and the drainage is effected by drifts—the depth from the surface being from 15 to 35 yards. The coal is sold at 5s. per ton. At Flockton, in this neighbourhood, a seam of 16 inches is worked.

These facts shew how very difficult it must be, to say before-hand what supply a given coal-field is capable of yielding—so many data remaining yet to be ascertained, before we can pronounce whether this or that bed should be taken into the account, or should be rejected as unlikely ever to become available.*

Origin of coal.—Let me now turn your attention to another branch of enquiry on which much obscurity still rests, and which should not be lost sight of, in a detail of objects deserving of your consideration.

* Answers obtained from our different coal-fields to the questions—What are the thinnest seams worked in your district, or which *at present* might be worked to profit?—What the peculiar circumstances (of quality, demand, facility of working, draining, &c.) which render them so workable?—would form a valuable addition to our practical knowledge on this subject.

Coal has been satisfactorily shown to be derived from accumulations of vegetable matter. But much remains yet to be explained in regard to the *kind* of vegetable matter—whether such as forms the peat bogs now existing, or such as constitutes the large timber rafts of the Mississippi. And if of large trees, to what natural orders they belonged, by what agent they were converted into coal; how the action of this agent was modified, and by what circumstances, so as to produce coals so different in quality; and what chemical change or series of changes the wood underwent, in order to produce this transformation. On one or other of these points a careful and minute study, of the appearances presented by the several beds of coal, and of the vegetable fossils they contain, may be expected to throw some light. The discovery for example, of a peculiar substance among the coal, at Middleton colliery in this neighbourhood, which I have since found also in Staffordshire, has led me both by its nature and the mode in which it occurs, to believe that among the trees from which the coal has been formed, were some, which like the pines and other kindred tribes exuded a resinous matter, of which the peculiar substance in question is the altered residue.* The occurrence of petroleum, in the roof of one of

* I have described three varieties of resinous matter occurring in the mineral kingdom :—

1°. *Middletonite* = $C_{20}\,H_{11}\,O$ or $C_{20}\,H_{10} + HO$ this appears to have been one of the ancient resins of the æra of the great coal formation, and is found in the Staffordshire, Leeds, and Newcastle coal-fields.

2°. *Retinic acid.*—The resin of Retinasphalt = $C_{21}\,H_{14}\,O_3$. This is a resin of the period of the Bovey coal deposit.

3°. *Guyaquillite* = $C_{20}\,H_{13}\,O_3$ or $C_{20}\,H_{10} + 3HO$. This occurs as a large deposit in the neighbourhood of Guyaquil, but with its geological position I am unacqainted.

They are all closely related to oil of turpentine = $C_{20}\,H_{16}$

$$\text{Thus } (C_{20}\,H_{16}) + 6O = \underset{\text{Middletonite.}}{(C_{20}\,H_{11}\,O)} + 5HO$$

$$(C_{20}\,H_{16}) + 6O = \underset{\text{Guyaquillite.}}{(C_{20}\,H_{13}\,O_3)} + 3HO$$

$$(C_{20}\,H_{16}) + 3O + CO_2 = \underset{\text{Retinic acid.}}{(C_{21}\,H_{14}\,O_3)} + 2HO$$

the coal-seams in the Whitehaven district, throws some light both on the cause and the nature of the chemical changes by which coal has been produced; while it almost renders certain the origin of the petroleum springs, so abundant in the East and West Indies and in South America. The fossil wax (Ozokerite) also, found in connection with the coal measures in Moldavia, in the Urpeth colliery near Newcastle, and in large quantity in the Linlithgow coal district, lends its aid, in lessening the obscurity which invests our present notions, in regard to the production of mineral coal. And in like manner every new observation will afford us *some* new light, till the theory of the formation of coal becomes perfectly understood. To myself it is at present an object of much interest, to collect from every quarter such mineral substances of organic origin as occur in the proximity of our coal strata, with a view to the elucidation of the chemical nature and origin of the coal itself, and of the gaseous substances or vapours which may exist in the atmosphere of mines. May I bespeak the co-operation of such of you as are practical men, to aid me in this research?*

The last formula shews that the retinic acid was probably not derived directly from oil of turpentine by the oxidation of the atmosphere.—*See London and Edinburgh Phil. Mag.*, xii. *and* xiii.

* The great mass of the *raw* material from which coal has been produced, must have been the fibre of wood, the *lignin* of chemists. Every other principle present in dead wood is insignificant in comparison with the amount of this substance. We may, therefore, consider coal such as we meet with in our coal-fields, and which exhibits still an internal organic structure, as essentially *changed lignin.* Now this substance, according to the most accurate analyses, may be considered as composed of carbon and water, or of carbon with oxygen and hydrogen in the proportions to form water. It is represented by the formula $C_{12} H_8 O_8$. We know, as I have stated in the text, nothing accurately in regard to the composition of coal, either because there are several definite species of coal which occur mixed with each other, and which we have no means as yet of distinguishing and separating, or because foreign substances are present in it in various proportions, by which our analyses are complicated and rendered irreducible into formulæ. The latest analyses of caking and cannel coals assign to these varieties the following composition :—

Heating power of different varieties of coal.—An examination of the different varieties of coal, which occur in the same

	Carbon.		*Hydrogen.*		*Oxygen and Nitrogen.*	*Authority.*
Caking (French) ...	89·04	...	5·23	...	5·73	Regnault.*
——— (Newcastle)	89·19	...	5·31	...	5·50	Richardson.†
Cannel, (Wigan)....	85·81	...	5·85	...	8·34	Do.
——— (Mons).....	86·49	...	5·40	...	8·11	Regnault.

The *approximate* formula deduced from these analyses is for caking coal $C_{20}\ H_7\ O_1$, and for cannel coal by the first analysis $C_{40}\ H_{16}\ O_3$, and by the second $C_{40}\ H_{15}\ O_3$. According to the latter, cannel coal differs from caking coal only in containing the elements of half an atom of water in addition, for $2\ (C_{20}\ H_7\ O_1,) + H\ O = C_{40}\ H_{15}\ O_3$.‡

During the decomposition of lignin, from the analogy of other organic substances we should expect water and carbonic acid to be among the principal products; and that if aided by heat, organic acids should be occasionally formed, and one or more of the numerous compounds of carbon and hydrogen. The carbonic acid, the water, and the organic acid should disappear, but the carbo-hydrogens being insoluble in water and occasionally volatile, should remain in or near the coal. The latter observation is in accordance with the fact that Petroleum and Ozokerite are occasionally met with in considerable quantity in connection with beds of coal.

If we compare the composition of lignin with that of the two varieties of coal above mentioned as represented severally by the deduced formulæ, we find that they confirm the view which analogy would lead us to adopt in regard to the formation of this valuable combustible.

For if from lignin $= C_{24}\ H_{16}\ O_{16}$ we subtract the
formula for Caking coal $= \underline{C_{20}\ H_7\ O_1}$
there remain $C_4\ H_9\ O_{15} = 3\,C\,O_2 + 9\,H\,O + C\,H$

or three equivalents of carbonic acid, nine of water, and one of a carbo-hydrogen, represented by C H. To this class of carbo-hydrogens, &c. belong Naptha, Hatchetine, and Ozokerite, all of which have actually been observed in connection with the coal measures.

Again, if from lignin $= C_{48}\ H_{32}\ O_{32}$ we subtract the
formula for Cannel coal $= \underline{C_{40}\ H_{15}\ O_3}$
there remain $= C_8\ H_{17}\ O_{29} = 6CO_2 + 15HO + (C_2\ H_2\ O_2)$

the residue in this case being equal to six equivalents of carbonic acid, fifteen of water, and two of each of the elements ($C_2\ H_2\ O_2$) in excess, from which may have been formed both organic acids and volatile or fixed carbo-hydrogens. Acetic acid for example ($C_4\ H_3\ O_3$) is very likely to be formed, and as $2\ (C_2\ H_2\ O_2) = (C_4\ H_3\ O_3) + HO$ it might be converted into acetic acid and water; or ulmic acid ($C_2\ H_1\ O_1$) is a product that might be expected, and

* Annales de Chimie et de Physique, lxvi., p. 353.
† Transact. of the Nat. History Society of Newcastle, ii., p. 405.
‡ The atomic weight of carbon in these formulæ is 76·437, and of hydrogen 12·4796.

or in different coal-fields, is not only interesting in reference to the origin of the differences they present—but it is important also as bearing on their practical value. The best coking coal of this county, in the most improved methods of charring, loses at least eight cwt. out of every ton—a loss of combustible material to which I shall hereafter advert. Other coals either cannot be coked at all, or give a coke of an inferior quality. Some coals again in the making of gas, yield from 30 to 35 per cent. less from the same weight than other varieties. The coking coal of Newcastle has this great advantage over the best coal from Staffordshire. The heating power, however, is generally speaking by far the most valuable quality of a combustible, and in this respect there are differences equally striking. The exact determination of this latter property appears to me to be a point of great practical importance, and one which deserves your serious attention.

On reaching a seam of coal, the adventurer examines whether it will yield a fuel suited for domestic purposes, for coking, or for raising steam,—and without enquiring what is its relative heating power, he regulates his proceedings by the answers he obtains to these three leading questions. But when there is a choice of coals, the manufacturer speedily discovers that

the residue ($C_2\ H_2\ O_2$) = ($C_2\ H_1\ O_1$) + HO or ulmic acid and water; or light carburretted may be produced, when $C_2\ H_2\ O_2$ would become $H_2\ C$ + HO or an equivalent of the gas with one of water.

Though therefore our uncertainty is still very great in regard to the true chemical nature of coal, and though the formulæ above given are only to be considered as approximations—the small quantity of nitrogen present being wholly neglected, yet we are able to form some idea of the way in which coal has been produced, and our ideas will become clearer and more correct as accurate observations on the coal strata are multiplied.

In this view of the origin of coal I have taken no notice of the small and probably variable quantity of nitrogen it contains. I have elsewhere stated that this element may possibly exist in the coal in the state of para-cyanogen, giving, when heated to redness, the ammonia and cyanogen met with in the products. In the carbonic acid given off during the change we see the origin of the *carbonate* of iron of our clay ironstones.

even among those of the same kind, one variety will generate more steam than another, and this variety he accordingly prefers. In reference to the economy of fuel, it is of great importance to know what quantity of steam a coal is fitted to generate, not in this or that arrangement of flues, but when the entire heat it is capable of giving off is applied in the best possible way. It is said that one pound of coal gives off heat enough to convert fourteen pounds of water into steam; and in practice it has been found possible so to apply it as to convert ten pounds into steam. The Cornish engines come nearest to this experimental maximum. The ordinary engines in our manufacturing towns rarely exceed seven pounds and a half; and in the vicinity of the coal-mines a much less proportion of water is converted into steam by one pound of coal.

But statements of this kind, it is obvious, can be compared with each other, only when the experiments are made with the same kind of coal. They must lead to error in regard to the relative value of different methods of combustion, when different coals are employed. If those of Staffordshire are found in practice, to be inferior in heating power to the bituminous coal of Newcastle by 30 per cent., we may well suspect differences to a smaller amount among the varieties, even of the same kind of coal, met with in the same field.

Three important consequences would follow from an accurate determination of the heating power of all the varieties of coal in a given district—

1°. It would afford a standard by which the value of each variety might be fixed, and by which the demand for it would be regulated. That a coal possessed a maximum heating power, would be an immediate recommendation to it. It would obtain, at once, a character which at present it can only acquire after the prolonged experience of practical men, and coals inferior in this quality would attain their true level in the market.

2°. A knowledge of what a coal ought to do, what quantity of steam it ought to produce, would lead to a great saving of fuel, by drawing the attention of the engineer to the construction of the fire-places and flues. Where the produce of steam was small, the blame could no longer be laid on the combustible; and it would become a common object of ambition, by improved arrangements to approach nearer and nearer to the maximum effect, which each coal by theory is capable of producing.

3°. There are certain varieties of coal in great request for the purposes of steam navigation, and the demand for these varieties has now become so great, as to add additional value to tracts of coal in Northumberland and Durham, which have hitherto lain untouched, because they could not be worked to a profit. But though their other properties fit these varieties of coal for use in steam-boats, it is by no means clear that they are really the best for this purpose, especially in long voyages, where much heating power in small compass is the greatest desideratum. Suppose, then, that examination should prove—and I have no doubt it would do so—that certain varieties of coal possess a much greater heating power, than those now generally burned in steam-boats, attention would be turned to those more valuable varieties; and the great aim among engineers would no longer be to obtain a coal which should burn best in their fire-places, but to contrive a fire-place which should most perfectly burn the most valuable coal. It would also lead to the adoption of different fire-places for different varieties of coal, and would in some measure put an end to that great disparity in the results, which, according to different observers, have been or may be obtained in steam navigation, from equal quantities of coal. Among the most elementary data in all such calculations, must clearly be reckoned the exact heating power of the combustibles employed.

The determination of this point requires a little chemical skill—at least a little attention to delicacy of manipulation;

but by the method of Berthier, an accurate result is soon obtained, and without great difficulty. I press it upon your attention, Gentlemen, as a subject in which a Society, located in a coal district, must feel much interest; and because connected, as many of you are, with the actual working and sale of coal, you must feel anxious to investigate every point, that bears upon the commercial value of a mineral, with which your pecuniary interests are so closely identified. At your suggestion, and under your guidance, the coal-trade of the district may be induced to turn their attention, to the comparative combustible value of the many varieties of coal which your mines produce, and to the mode of obtaining an accurate determination of this value for each variety. While these determinations would be productive of the benefits to which I have adverted, they would also occupy an honourable place in your future transactions.*

Ultimate analysis of coal.—The ultimate analysis of coal is a subject which in a theoretical point of view is full of interest. Such analyses as have yet been made show that there are greater chemical differences among the coals, even of the same district, than the practical man is prepared to expect. Of the true chemical nature of coal, however, we as yet know very little; and I bring this enquiry before you in the hope that, though not so immediately practical or connected with the economy of your mines, as that to which I have just adverted, it may, nevertheless, meet with some one among your

* The following table shows the relative heating powers of certain combustible materials, determined by the method above alluded to, according to Dr. Forchhammer (De Bornholmska Kulformationer, p. 6):—

Turf	1
Beach wood	0·862
Danish coal (Bornholm)	1·275 to 1·524
Swedish coal (Högenäs)	1·611
Faroe coal	1·672
English (Newcastle)	2·256
Scotch (?)	2·387

number who may wish to prosecute it. The time, I hope, may come when, as a Society, you may consider it not unimportant to take some public steps towards removing a portion of the obscurity which still hangs over the true composition of coal.

Structure of coal.—The structure of coal is another curious subject of enquiry. You are familiar with the fact that the greater number of the coal-beds exhibit one or more cleavages in directions which are more or less variable. The principal cleavage, under the name of the *cleat*, from the facility it presents to the working of the coal, generally regulates the direction of the boards and headways. What is the cause or origin of this structure? Does it depend on the chemical nature of the material itself—on the nature of the chemical changes which the vegetable matter has undergone—on the quantity or quality of the gaseous matters that have been evolved during these changes—on the heat to which it has been subjected for a long period—or on the pressure of the superincumbent rocks? Is it an effort, more or less rude, towards crystallization, the mutual attractions of the particles being to a certain degree modified or restrained by the foreign matter with which they are mixed—or is the whole due to a mechanical cause, extrinsic to the stratum itself?

The latter supposition indeed is hardly admissible when we consider that the cleavages have often different directions in the successive layers which occur in the same coal seam;* that in some districts workable beds occur, having either no

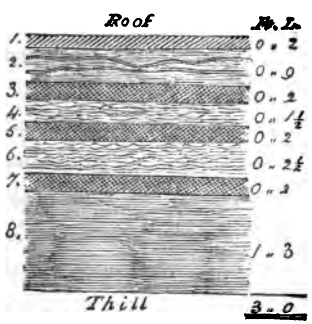
* For the following section of the Middleton main coal I am indebted to my friend Mr. Embleton:—

"The direction of the cleat in this colliery varies from N. 20 W. to N. 32 W., and is not in the least affected by the dip. This is the fracture which is the guide to the workmen in driving their endings (headways) and boards—the former being driven parallel to it, and the latter at right angles. There is, however, another fracture which is not attended to in working the coal, and has not, I think, been much observed. It forms with the cleat and horizontal parting a rhomboid or cube as the case may be; with us its course is from N.

cleat at all or only a very obscure cleavage,† while many fathoms above them are found others, in which the cleavage is very distinct, and greatly facilitates the excavation of the coal; and that generally speaking it is no way dependant on the dip, nor altered by changes in the angular inclination and strike of the beds.

Fossil remains.—I need not advert to the many interesting enquiries connected with the changes which took place on this part of the globe, during the deposition of the successive beds of coal, shale, and sandstone, of which your coal formation consists,—with the plants which grew on the dry or swampy

29 E. to N. 42 E. For example, the yard coal is composed of 8 layers of coal.



The N.W. fracture is 30° West of North.
The other fracture in No. 5 is N. 29 E.
Do. in No. 6 is N. 33 E.
Do. in No. 8 is N. 42 E.

This is the result of a few trials, but I do not offer it as anything more than an approximation to the truth. The fracture of the remaining layers I have not ascertained. I find much difficulty in obtaining the angle, owing, I suppose, to the imperfect instruments used. The layer No. 1 is very bright and shining, and contains little earthy matter. No. 2 is rather more earthy and contains bright undulating layers, as shewn above. No. 3 has a dull aspect, and is more earthy than either No. 1 or No. 2. No. 4 is nearly similar to No. 2, but the bright streaks are less continuous and distinct. No. 5 and 7 are similar to No. 3, and so is No. 6 to No. 4. No. 8 is very bright and shining, and, unlike what lies above, produces brownish ashes when burnt. What effect may the quantity of earthy matter have on the fracture?"

The second or *short* cleat, so called in opposition to the regular cleat by which the workings are regulated, and which exhibits larger continuous fractures, forms in the county of Durham, *generally* a right angle, in the Whitehaven and Edinburgh coal-fields more frequently an acute angle with the *long* cleat. The former produces what is sometimes called *cubical,* the latter *rhomboidal* coal.

† In South Hetton colliery, near Durham, at which locality the Hutton seam is deeper than elsewhere, the cleat is hardly discernable though well marked in other collieries at a short distance. Where the distinctness of the cleat varies, the coal is observed to become more tender as the cleavages become more distinct.

places, and which still preserve an erect position, apparently that in which they grew—or with the many strange animals which lived in the waters, and of which the remains are so abundantly preserved near the surface of your coal-beds. To such enquiries your minds will turn—spontaneously turn—with continually renewing interest and wonder, and you will anxiously collect the relics of those ancient times for preservation in your museum.

I may perhaps be permitted to direct your attention to one or two of the spots in your series of strata, in which your curious search for specimens is most likely to be rewarded; and the accurate examination of which may be expected to throw some light on the ancient condition of this portion of the globe,—on the forms, habits, and structure of the races by which it was tenanted—and on the origin and mode of deposition of the beds in which they are laid up.

Coal measures.—You are aware that in some of the northern coal-fields, remains have been found in considerable abundance, chiefly of large fishes (megalicthys) of remarkable and unexpected structure, comprising single bones, scales, rays, heads, and other detached portions of the skeleton. Of such remains your coal is far from being destitute. The Low Moor district appears, if we may judge from the experience of the past, to be the richest in such fossils,—two of the finest heads of fishes of this class hitherto observed, being the specimens, from that locality, in the possession of the Literary and Philosophical Society of Leeds. But abundant indications of fossil fish are to be met with in the bituminous shaly roof which immediately covers several of your coal-beds. Scales and small teeth are plentiful, immediately above the coal at Middleton; they may be seen also in great numbers in the same position at Low Moor. Follow these indications, and you are sure to be rewarded by larger discoveries. At Middleton, these fossils had hitherto escaped attention from a portion of coal being left to form a roof by which the

bituminous shale was concealed. The same covering may have prevented discovery in other localities.

The existence and geological position of many of the magnificent fossil vegetables with which your coal-field abounds are well known to you. From those subterranean forests which still stand erect above some of your coal seams, telling you of different climates and of different landscapes in times far remote, you will not only root out entire trees, but you will also gather fruits and flowers to adorn your collection; and in the varied vegetable productions which your successive strata afford, you will endeavour to discover some distinguishing marks, by which the place of each bed in the series may be more or less perfectly determined.

Magnesian limestone.—What was the origin of your magnesian limestone? Was the magnesia derived from matter sublimed by the agency of subterranean heat as Von Buch supposes, or was it deposited, like some of our common limestones, at the bottom of the sea, by the agency of springs loaded at once with calcareous and magnesian earths? If the latter, do the varieties in the texture of the limestone throw any light on the position of those springs? Does its porosity in one place, its honeycomb structure, indicate the escape of gas and the neighbourhood of the original sources? Does a compact variety indicate deposition at greater depths and in still water—does the granular suggest the notion of a gentle flow of water—does the oolitic, as at Hartlepool, tell of gentle undulations, of shallow water, or of the gradual ebb and flow of a summer sea?* Again, the tops of your magnesian limestone ridges present indications of coral reefs.

* Professor Sedgwick, who has studied this deposit with great care, considers it to be of mechanical origin, and that the variations in its internal structure are metamorphic.—*Geol. Transac., 2nd series, vol. iii., p.* 123. The mountain limestone to which he refers seems to be an exceedingly doubtful source for so large a quantity of magnesia, and granting the internal structure to be metamorphic, still the honeycomb appearance must be assigned to a specific cause.

You will find such in the immediate neighbourhood of Leeds. Are these universal, or are they confined, as in the county of Durham, to particular spots, and those at the upper part of this series of rocks? Does this seem to indicate that the mass of the magnesian limestone was deposited from springs little aided by testaceous animals, and only assisted in its ascent by corallines, when it had already reached within a short distance of the surface? Is the comparative scarcity of fossil remains in this limestone, any proof of its being an enemy to organic life? Does not the fact, as I have found it, that the encrinal columns in this rock,* are a purer dolomite,—contain magnesia in greater proportions than the mass through which they are disseminated,—speak strongly in favour of the contrary opinion? May not the depth at which it was deposited have been unsuited to the habits of the shell-fish living in that ancient sea?

Fish bed.—Beneath the magnesian limestone lies the lower red sandstone—the Pontefract rock of your district. Is there no deposit between these two? No fish-bed corresponding to that in the county of Durham, and occupying the place of the copper slate (Kupferschiefer) of the German geologists? For this fish-bed your collectors will look with interest. Near Durham it consists sometimes of a mere parting of blue shale or clay a few inches in thickness, at other times the blue clay diffuses itself over several, in some localities as much as ten feet of the lower part of the limestone, making it more or less slaty; while in other places at a short distance, it forms a thin slaty calcareo-magnesian sandstone

* Different specimens from Humbledon Hill, near Sunderland, have given me the following results :—

	Carbonate of lime.	*Carbonate of magnesia.*	*Insoluble matter.*
Perfect encrinal columns	57·88	41·84	0·28
Mass consisting in great part of columns	60·41	38·78	0·81
Another portion with fewer columns	62·01	——	——
Another	62·20	36·93	0·87

of five or six feet in thickness. The partings are caused by thin layers of clay, and exhibit numerous impressions of fish, with teeth and scales of various sizes. The search for this bed in your district may enrich your museum with many valuable specimens.

Lower red sandstone.—The lower red sandstone itself will also present you with several questions. Was it deposited slowly, as the coal measures generally were, in successive layers at successive intervals, or was it all accumulated in one short period of floods and convulsions? and were these convulsions connected with the opening of the springs which poured out the magnesian waters? Plants also occur in this sandstone, and the collections you will form may perhaps decide the question whether they are identical in all respects with those which your coal measures furnish so abundantly and in such perfection.

I will not detain you by referring to any of the other strata, either higher or lower, than those I have mentioned, as, with the exception of the millstone grit containing a few vegetable remains, they are not developed to any extent, near the centre and sphere of your most important operations.

Nor need I impress upon you the fact, that the more those connected with the practical working of coal make themselves acquainted with the general principles of geology, as well as with the phenomena immediately under their eye, the better will they be prepared for the right interpretation of any new appearances which may present themselves, and the better furnished with resources for meeting new exigencies.

Let me illustrate this by an example.

In the county of Durham trap dykes occur in various localities. On approaching these the coal begins to assume a peculiar charred appearance, till close to the whin it is completely changed into a useless stony coke.* The intelligent

* Beneath the town-moor of Newcastle the coal is spoiled by a dyke "for

viewers in Northumberland and Durham are accustomed to such appearances, and reasoning on the fact that a hot mass in cooling contracts in bulk, and therefore that the plane of trap in the dyke may, in solidifying, have narrowed, and left an empty space on one or both of its sides, by which water may descend—they make their approaches to it with great caution. That in a given locality no water has descended, does not authorise them to overlook the indications of theory, so that in every case the requisite precautions are carefully observed. In this county (York), where trap dykes have not hitherto occurred, the viewer not understanding or neglecting the peculiar change in the coal, might drive boldly forward and drown the mine.

Depository of mining records.—Apart from actual enquiry there is, in connection with the economy of coal, another important service still, which your Society may render to this district—by making your museum or your transactions, a depository for the records past and present, of the various mining operations, undertaken in the several localities, in which coal shall from time to time have been worked.

You are familiar with the fact that there are in all coal-fields important deposits, which local or other circumstances prevent from being worked to profit; large tracts of land in which after the best coal is extracted mining must cease for an indefinite period, and the pits be abandoned. But when circumstances change, how important will it be to the new adventurer, to have accurate information in regard to the extent and exact position of ancient workings—how much expence will be spared him, how much danger prevented! Even in districts far from being exhausted, how many accidents have occurred from imperfections in plans, or from a total loss of the records of ancient operations. But unless

upwards of 100 yards in breadth." At Haswell colliery, near Durham, "there are about 40 yards of strong cinder coal in the neighbourhood of the dyke, which emits little or no gas."

some general means be adopted under the direction of an influential public body, it is much to be feared that the plans of many existing workings may be lost, and even their very sites forgotten. It is therefore of importance, at once to the nation at large and to the district in which mines are situated, as it is obviously the peculiar interest of the possessors of manorial rights, that distinct accounts of all mining operations should be securely preserved, and copies of all plans be placed in a safe and common registry.

As early as the year 1797, public attention was drawn to this subject by Mr. Thomas, of Newcastle, who recommended the establishment of an office at Newcastle for collecting information regarding the collieries in the neighbourhood; in which office were to be deposited by the viewers, plans of the boundaries, workings, &c., of their respective mines.

At a later period the same plan was agitated by Mr. Thomas Chapman, civil engineer, and improved regulations suggested; and Mr. Holmes afterwards proposed that the office should be established by act of parliament, and supported by a rate of one penny per chaldron on all coals raised.* Up to the present time however, nothing has been done to accomplish this object,—the mutual jealousies of the coal-owners being probably one obstacle against its being effected. With the progress of knowledge, however, this and other impediments are gradually disappearing, and a plan which promises so much future good to so many different parties, must ultimately meet with numerous supporters.

Mr. Buddle has recently revived the proposal under a another form. He suggests that in the museum of the Natural History Society, a division should be set apart for the reception of documents of the description above alluded to—that they

* Holmes, on the coal mines of Durham and Northumberland. (London, 1816; p. 218.) A much smaller rate would be sufficient now.

should be under the charge of the committee for the time being, and should be open to the inspection of such persons as they shall think proper, at a small charge, to be levied for the benefit of the funds of the Society.

The information to be embraced in these documents Mr. Buddle arranges under the following heads; and he has illustrated* his views at great length by an admirable account of the Wallsend colliery, considered in these several points of view:—

1°. Name of the proprietor of the surface and minerals.
2°. Locality and extent of the property.
3°. The number and description of the seams of coal and other minerals it contains.
4°. The thickness and quality of the several seams of coal; which of them have been worked—to what extent—and why the working of any of them has been discontinued or not commenced.
5°. The winning of the colliery.
6°. The system of working.
7°. The dip and rise of the colliery, and description of the several slip dykes, &c.
8°. Accidents by explosion.
9°. What other accidents have happened in the colliery, and their causes.
10°. The system of ventilation practised.
11°. General observations.

To these should be added the quantity and quality of the water at different depths, and the economical purposes to which it is applied,† and also, as originally recommended by Mr. Chapman, a map of the district exhibiting "a delineation of all the roads, brooks, and principal objects permanently

* Transactions of the Nat. Hist. Society of Newcastle, II., p. 311.

† See page 47 and seq.

situated on the surface, with the magnetic bearing and date."*

The opinions of a practical man, so eminent in his profession, will be duly appreciated by you, and if the importance of the subject do not at once appear, will lead you to give it your anxious consideration.†

The experience of the past urges us to make the wise provision for the future, which is pressed upon us by the considerations above advanced. Besides the coal left underground from necessity or from waste, much has been also left from a want of *general* plans of the workings of a district, and of a general system of mining operations. Independent excavations have been made and are still making—in which, from the want of concert or of agreement among the parties, or of an accurate knowledge of boundaries, pillars and barriers of great extent are occasionally left, which there will hereafter be no possibility of removing.‡ Such irreparable losses, in some localities at least, might easily have been avoided, and the removal of this source of waste would not be more advantageous to the public interests, than it would be to those of private speculators.

* The construction of two different maps consequently will engage your attention :—

1°. A *geological* map exhibiting the outcrop, strike, and angular dip of your several coal seams—the lines of fracture or fault—the amount of throw, and its effects on the dip—with the course of the trap dykes, if any.

2°. An *historical* map of the surface shewing the boundaries of the several mines—marking by particular colours those localities and seams which are worked out consecutively.

† Since the above was in the printer's hands, a friend in Yorkshire, well acquainted with this subjeet, has written to me as follows :—

"In colliery leases, about which I am consulted, there is always a clause inserted to compel a lessee to keep a correct plan of the workings, and to shew on it the particular position of each part or portion of the coal unworked. If a legislative enactment could be had to compel parties to deposit a duplicate of workings in a place of safety, it would be of great benefit to the mining community."

‡ See Professor Sedgwick's evidence before the House of Commons, 1829; p. 232.

OBJECTS, as a Polytechnic Society.—The geological structure of your district, whether viewed with the eye of a man of science or with that of an economist, presents, as you see, many subjects for investigation, by the prosecution of which you will not only enlarge your own information and add to the stock of general knowledge, but contribute at the same time to your private interests and to the resources of this great county. But there are yet others of no less practical importance embraced by your title of a Polytechnic Society. These relate chiefly to the proper development of your resources; the best mode of availing yourselves of *all* the riches you possess; and of doing so with the least possible waste.

The two subjects which appear to me to have the strongest claim on your notice in this branch of your enquiries are, the ventilation and draining of mines and the improvement of the iron manufacture.

I.—*Ventilation of mines.*—In coal mines two kinds of noxious air are chiefly met with, known familiarly by the names of the fire and choke or after damps. The former is the light carburetted hydrogen emitted in hot weather from marshes and stagnant pools—the latter is carbonic acid. The fire damp is given off generally from the coal. It must be supposed, however, to fill all the cracks and cavities immediately above or below the coal. The choke damp escapes principally from the roof, and in greatest abundance from the cracked roof of old workings, and from the neighbourhood of beds of ironstone. In the lead mines it is given off in streams from the fissures in the limestone, and it is the invariable product of explosions of fire damp, filling the mine and *choking* the unfortunate workmen, who may have escaped the violence of the fiery blast.

Fire damp.—The vast quantity of inflammable air given off in many of our coal mines, and the fatal effects which ensue

when it happens to be kindled, have long ago rendered the removal of the gas and the prevention of explosions, a subject not only of importance to those concerned in the working of coal, but of deep interest also to every humane mind. The first and most obvious method of diminishing the evil was by an improved system of ventilation. I need not detail the successive steps by which the ventilating of mines has been brought to its present state of comparative perfection—under the auspices especially of Mr Buddle,—for these are already far better known to many of you than I can be supposed to understand them. I would suggest it, however, as worthy of your constant thought, whether the prevailing system is not really susceptible of amelioration—whether the general employment of an air meter* in your drifts would not enable you to measure the actual quantity of air transmitted through them in a given time, and to regulate that quantity by the existing state of the atmosphere in the mine—and whether it would not be possible to have such an arrangement of furnaces as to give the power of throwing in a fresh current of air on any sudden emergency. It is true, that by increasing the fires in the ventilating furnaces you can increase the current throughout the mine to a certain extent—but in addition to those required in the ordinary state of things, would it not be an additional precaution in a dangerous mine, were there one or two unused furnaces, kept in such a state of preparation, that in a few minutes they could be kindled, when any sudden emission of gas was perceived or suspected. Without pretending to judge how far

* Besides the lately invented anemometers which might be made susceptible of application to this purpose, a machine has lately been contrived for special use in coal mines, by Mr Thomas Elliott, overman at Pensher colliery, and for which the coal trade of the Tyne has handsomely presented him with a premium of ten guineas. The current of air in the working is made to act on four arms, like those of a windmill, connected with a series of wheels and a dial plate. On this dial plate the velocity of the wind is indicated by two pointers, and the *average* rate registered for two or three days together. The only thing further to be desired is, that it should register the *variations* of the rate during a given period, and the *instant* of variation.

such an additional expense would interfere with the fair profit to which the coal-miner is entitled, I would ask you also if *perfect* safety might not be ensured by the sinking of a greater number of shafts in fiery districts. In whatever way indeed you can contribute to the perfecting of ventilation, whether by the methods now suggested, or by the adoption of any other precautions—you will equally benefit yourselves and your country. That which may preserve the lives of thousands of your fellow-creatures, cannot be unworthy of the deep consideration of your society,—and the fear of incurring a little additional expense, will not deter your enlightened coal-owners from adopting your suggestions.

With the invention of the Davy lamp—the circumstances that led to it, and the blessings it has conferred on mankind at large—you are all familiar. It has been adopted in every country where inflammable air is met with in the working of mines, and foreign nations have vied with his own countrymen in testifying their obligations to its distinguished discoverer. This lamp was never intended to enable the workman to continue his labour in *every* atmosphere—but to serve only as a shining Mentor to tell him of approaching danger, and to give him time for escape. You are aware that objections have, from time to time, been made against this lamp. Cases have occurred, it has been said, in which it did not prevent danger—some in which the flame actually passed through, and caused the combustion of the inflammable mixture of which the atmosphere was composed. Enquiries also have been set on foot to weigh the merits and demerits of this admirable instrument, and various so-called improvements have been made or suggested in its construction. With the results of these enquiries I am by no means satisfied, or that the improved lamps are not more faulty than the original Davy. In most cases of accidents where this lamp was in use, the fault has been traced to the carelessness, the culpable negligence, or the rashness of the workman—and it has not been found,

I think, that any of the altered lamps are so much more likely to be safe—in the case of those extraordinary emissions of inflammable, perhaps peculiarly inflammable, matter, supposed at times to occur,—as to compensate for the inconveniences attendant upon their ordinary use. I give this opinion, however, rather with the view of provoking enquiry on your part, than of putting an end to discussion. If the lamp has faults, they will at last be established, and you would deserve well of your country could a committee of your body draw up a clear report of the circumstances in which the Davy lamp will not warn the miner of his danger, in ample time to allow of his escape. You would deserve better could you contrive another, which, while equally perfect in theory, and as commodious in practice, should be a surer guide, and a more efficient protector to the endangered miner.

It is supposed by some that perfect safety in the working of our coal mines is hereafter to be ensured, by the discovery of some means of neutralizing the dangerous properties of the inflammable air. The present state of our chemical knowledge, I fear, holds out no hope of the discovery of any such means of safety—at once consistent with the comfort of the workman and economical enough to permit of its universal application. Could we even anticipate such a discovery, safety lamps must still be used, for a chemical agent could only act like ventilation in removing the gas already existing in the atmosphere. It could not penetrate the cavities of the living coal and neutralize it there. We should still be subject to sudden rushes of explosive materials and to all those evils, attributed, however unjustly, to the imperfect construction of the lamps now in use. You will act unwisely, therefore, if you indulge in hopes of assistance from such a quarter. Let your efforts be directed rather to the testing of the Davy lamp and to the improvement of ventilation.*

* Ventilation connects itself also with another practical question, to which

Draining of mines.—In regard to the *draining* of mines, the observations on the dislocations and dip to which I have already alluded will be of material advantage—but an important part of your enquiries on this subject will have reference to the construction, power, work done, and fuel consumed by the steam-engines attached to your mines. Under your superintendence the efficiency of the Yorkshire may in time be brought to rival that of the Cornish engines, and with a view to the attainment of this end, I cannot recommend to you a better stimulus than periodical returns of the duty done by each, such as have long been published in Cornwall.*

reference has already been made. Is it not possible to cool, as well as to purify the air in a mine, by a sufficiently rapid current? May we not render *very* deep mines workable by fresh accessions of cold air from the surface? There can be no question that to a certain extent such an effect must follow, but to what degree this end may be attained, can be determined by experiment only. We know that by ascending from the surface in our island, about 270 feet, the temperature diminishes 1° (F.); in descending into the earth, therefore, the increased density alone will cause an increase of temperature in nearly the same proportion. A current of air, with whatever rapidity it might descend, would consequently, at the bottom of a shaft 300 fathoms deep, be about 7° (F.) warmer than at the surface. The mean temperature at the surface being 50°, that at the bottom of the shaft would be about 57° (F.) But the shaft is in reality a hot tube from which the air absorbs heat, in extreme cases, with almost inconceivable rapidity. Thus at Middleton collieries during the extreme cold of last winter, the air at the top of a shaft was 17° (F.), while at the bottom, only 432 feet, it was 25°, though it was rushing down at the rate of 320 feet in a minute. Theory, therefore, does not enable us to say what degree of cooling effect is possible in very deep mines. And if workings be so extended that the length of the air courses should stretch to several miles† we can understand that though a considerable cooling effect *must* take place from rapid ventilation, it will not be so great as we might either wish for or expect.

† At Hetton colliery, near Durham, the length of the air courses is from 3 to 11¾ miles.

* Answers to such queries as the following, would form a valuable record in your transactions:—

Pumping engines.—Condensing or non-condensing? double or single? diameter of cylinder and length of stroke—length of stroke in the pit? diameter of the working barrel in the pumps—quantity of water raised and of fuel expended? what feeders met with in sinking—at what depths from the surface—what quantity of water discharged by each—how were the feeders stopped during the sinking—from what depth is the water now raised by the pumps?

Winding engines.—Condensing or non-condensing? diameter of cylinder and

Connected with the draining of mines is an enquiry into the absolute quantity of water found in them—the geological position of the feeders from which it springs—its quality or chemical constitution—the inferences to be drawn from the occurrence of certain qualities of water at certain depths—and the economical purposes to which it may be applied. In the Durham and Newcastle coal-field, salt springs are frequently met with and often at great depths. They occur in the workings of the Main and Low main coals on the Tyne, and of the Hutton seam on the Wear. In some mines the brine is so strong, and the feeders so abundant, as to make them exceedingly valuable for the manufacture of salt. During the war, much of the soda exported from the Tyne was obtained from the salt afforded by a spring in the possession of Messrs. Losh & Co., which was specially exempted from duty; and at present a great part of the ordinary consumption of salt for domestic purposes, in the interior of the county of Durham, is supplied by the salt springs met with in the coal mines near Birtley and Lambton. The spring at Birtley rises from what is there called the main dyke, in the workings of the Low main coal, at a depth of about 70 fathoms. It yields about 60 gallons a minute, and the salt manufactured from it amounts to 1500 tons a year. The bittern is also boiled down and sold for the manufacture of sal ammoniac.

What is the source of such springs? Do they come from the sea? Does the water resemble that of the sea—in what respect and to what extent? Does it indicate deposits of rock salt at great depths—or does the quantity of lime (bittern) it contains, render such an origin unlikely? To such questions as these you will naturally seek for replies.

In the Leeds coal-field springs of water, possessed of pecu-

length of stroke? weight of rope and of corf loaded and empty? depth from which it is raised, time of drawing it, and fuel expended?

liar properties, occur in a particular part of the coal series, which may possibly afford a means of identifying the strata. The Holbeck water is well known in Leeds for its softness and detergent properties, and is highly valued not only for domestic purposes, but also for its use in the manufactories. The principal foreign ingredient in this water is carbonate of soda, of which, according to Mr. George and Mr. West,* one imperial gallon will yield 102·4 grains in the state of the crystals of commerce. Similar water has been found at Bradford, at Huddersfield, and at Stanley near Wakefield, where it is said to contain still more alkali. In Mr. Wilson's Falconer pit, near Kexbrough, it was met with at a depth of 50 or 60 fathoms, and was recognised by its forming at the bottom of the steam-boiler a crystalline deposit some inches in thickness, and which was with difficulty removed. Similar water is said to occur in different parts of the North Riding, beyond the limits of your coal-field, but under what circumstances, except that, among others, it occurs in the disturbed district of Harrogate, I am not aware. The observation made at the Falconer pit seems to indicate that within the coal-field it occurs in particular strata: it will not be an uninteresting enquiry to you, how far this is the case, and whether its occurrence may be regarded as a constant index of the proximity of those strata.

Such springs as these are deserving of attention in an economical point of view. One pound of coal is capable of converting into steam ten pounds or one imperial gallon of water. It may procure for us, therefore, 102·4 grains of soda of commerce from the water, such as it is at Holbeck, and more from that which occurs near Wakefield. At this rate, one ton of coal would yield 32 pounds, or 70 tons would evaporate as much water as would supply one ton of crystallized carbonate of soda. At five shillings per ton of small coal the cost of 70

* Transactions of the Literary and Philosophical Society of Leeds, I., p. 20.

tons would be £17. 10s.; at three shillings per ton, a rate at which a boiling-house, erected near many of our pit heaps, might be supplied, the cost of fuel would be £10. 10s., very nearly the exact market price at which the alkali manufacturers of the Tyne are now selling their soda. Of course, it would be impossible, at present prices, to extract the soda from this water at a profit, but a few years ago it might have been a very profitable branch of manufacture. In 1828, soda was selling at £25. per ton, and in 1818, at about £38.; at either of those periods, but especially at the latter, the Holbeck water would have been almost as valuable as a coal mine, had its economical relations been understood.

What a lesson does the above fact read us of opportunities neglected and lost—what a stimulus does it supply to a more watchful care for the future—how distinctly does it point out one of the paths along which your youthful society may beneficially direct its steps?

Even now the concentrated liquor of the steam-boilers, where many are at work, is susceptible of useful applications, and ought not to be wasted. Might not a use be found for it in scouring the woollens of the Leeds cloth dressers?*

With the springs themselves are connected the deposits in your boilers. Nothing should escape your prying observation. From useless deposits and waste materials new truths are often elicited. The sediment from a boiler at Team colliery, near Newcastle, has lately furnished me with a new saline compound previously unknown to chemists—the composition of which throws light on some points of chemical theory, and even suggests new considerations in regard to the circum-

* *Queries.*—Qualities of the springs which occur at different depths. Are any of them remarkable for softness or otherwise? At what depths does the water become brackish, and in the neighbourhood of what seams? At what depth is the saltness greatest? Do the salt or soda springs occur generally in the neighbourhood of faults (slips or dykes)? At what point in descending does water cease to be observed?

stances under which certain mineral deposits have been produced.

II.—*The iron manufacture.*—Of the various manufactures of Great Britain few can compete in importance with that of iron. The quantity of pig iron annually produced in this country is at present about one million of tons.* Estimated at £5. a ton, the value† of raw pig iron alone amounts to five millions sterling a year. The conversion of upwards of one-third of this quantity into bars, must add at least another million to the value of the trade.

In the West Riding of Yorkshire this manufacture holds a prominent place in the industry of the county. In 1836 the produce of pig iron was 55,120 tons, since which time it has increased to about 66,000 tons.

* In 1836 the returns were—

South Wales	351,000 tons.
Staffordshire	282,360 ...
Scotland	98,800 ...
Shropshire	93,860 ...
Yorkshire	55,120 ...
North Wales	22,880 ...
Derbyshire	16,593 ...
Newcastle (about)	5,000 ...
Forest of Dean (about)	4,680 ...
Total	930,293 tons.

The produce of pig iron in 1826 amounted only to 560,000 tons; we may therefore safely infer that the total produce in 1838 cannot be far short of one million of tons.

† This value is an exceedingly fluctuating quantity, since the price of pig iron was in—

	1825.			1837.			
	£.	s.	d.	£.	s.	d.	
No. 1	12	0	0	5	0	0	per ton.
No. 2	11	10	0	4	15	0	......
No. 3	11	0	0	4	10	0	......

If we compare the relative prices and quantities produced at these two periods, we find the gross value of the whole iron produced to be very nearly the same—that is to say, *the public have reaped nearly all the benefits resulting from improvements and economy in the manufacture.*

The successful cultivation of this branch of manufacture depends upon two classes of circumstances totally distinct from each other :—

1°. On procuring the necessary minerals, abundantly, of good quality and at a cheap rate.

2°. On the improvement of old methods or the introduction of new processes, by which materials, labour, or time may be saved.

Materials.—*Coal.*—In regard to one of the materials—the coal necessary for smelting—I need only recall to your minds the observations already made on the importance of knowing the heating powers of different varieties, and point out the economy of employing in the furnaces such as give most heat with least waste—and such as contain the smallest quantity of foreign matter. The loss attendant on the process of coking merits a separate consideration.

Ironstone.—It is of importance to the development of local industry that the number, thickness, geological position, geographical extent, and peculiar characters of the ironstone beds occurring in your district should be ascertained. The mineralogical characters also—the chemical constitution—the produce per cent. of iron, cast or bar, and the quality of the iron, hot or cold short, yielded by the mineral from each deposit—the quantity of coal and limestone required by each variety to produce one ton of pig and bar iron ;—these are all questions which your Society may fairly submit to the attention of its members, as likely to afford accurate data for a proper estimate of your resources, of the extent to which the iron-trade in your county may be developed, and of the line along which that development may most safely proceed.

Many of these inquiries are of an immediate practical tendency, inasmuch as the cost of transport, as well of the raw material as of the finished bars, renders the choice of a site an important consideration in the establishment of smelting furnaces.

Limestone.—It is not always the case that the third of the necessary materials, the limestone, can be obtained cheapest and best where the other two abound most. Yet on this point something still remains to be done. New limestone deposits may be discovered, or others not supposed to be available may be turned to use, and, above all, the opening up of communications by canals and railways may bring within reach deposits of this mineral not hitherto had recourse to. How far the facility of communication may lead to improvements in this manufacture, is illustrated by the practice of the iron-masters in the neighbourhood of Dudley. Few places seem better fitted for the site of iron-works than the country round Wolverhampton. In the midst of a coal-field in which iron ore abounds, with the limestone quarries of Dudley and Walsall on either hand, it has been long known for its numerous furnaces and forges.

The *blue* lime of Dudley, which alone is sufficiently pure for the purposes of the smelter, forms two beds about 12 yards each in thickness, separated from each other by a considerable mass of thin argillaceous beds. This limestone was universally employed in the iron furnaces of the neighbourhood, till the year 1825. The use of lime, in the smelting of iron ore, is to remove the clay and other earthy matters, which the English ores contain in large quantity. It is of importance, therefore, to obtain a limestone, itself as free from clay as possible. But the lime from Dudley was not always carefully separated at the quarries from the clayey matter with which it is in contact; and complaints are said to have been unheeded.

It is certain that in 1824, when the iron rose in the market, the proprietors of the quarries raised the price of the limestone to the smelters, and in the succeeding year, when a reverse came, refused to make a corresponding reduction. This, with the previous dissatisfaction, caused the iron masters to turn their attention to Staffordshire; and from Caldron

Low, near Leek, they obtained a limestone so much better in quality, that the same quantity of iron was produced with one-third less than it was necessary to employ of the stone from Dudley. This difference not only defrayed the additional cost of transport, but by producing less slag and causing a less consumption of fuel, introduced a decided improvement into the trade. The opening of a new canal has since led to the employment of a limestone from Llangollen, in North Wales, which is superior to that from Dudley by about 7 per cent.

It is interesting to remark how the arts progress in spite of obstacles, and how the means adopted by individuals for their personal profit only, often lead to large diminutions of their private gains, while they bring accessions equally large to the national wealth. The loss to the owner of the Dudley lime works, by this change, is said to be not less than £5000. a year.

Your duty, then, in reference to this element of your prosperity, is to enquire what subordinate beds of limestone may exist among your coal measures—how far they are available for smelting purposes—and how you can facilitate the transport from a distance, of what your own mining field does not adequately supply.

Fire clay.—Among the subordinate sources of wealth contained in a coal-field, I may here advert to the beds of fire clay and of fire stone, such as forms the bottoms of your furnaces, as not undeserving of your attention. You are all familiar with the importance and value of the Stourbridge clay, in Staffordshire, and can understand how the proximity of such a deposit may render an adjacent coal seam workable, which otherwise it would be impossible to excavate at a profit. Apart, therefore, from their own independent value, and their connection with your local manufactures, it will be important to distinguish, in your contemplated section of the strata, accurately the locality and geological position of such beds, not

only as a means of identifying the several seams of coal among which they occur, but also as forming an element in the calculation whether this or that seam is likely to pay the cost of working.* Such was the case for example, in regard to the coal-field of Högenäs, in the south of Sweden. This district, so valuable to that country, as containing the only fossil fuel it possesses, had hitherto been ruinous to its proprietors, and was on the eve of being abandoned. A forcery engineer, however, was called in to report on the possibility of working the combustible to greater advantage, and among the probable sources of future revenue he pointed out, a bed of excellent fire clay held a prominent place.

Improvements in the iron manufacture.—Among the most important improvements recently introduced into the iron manufacture of this country, may be reckoned,—the introduction of the hot air blast,—the partial abandonment of the refining process,—and the working up and re-smelting of the finery cinder.

1°. *Hot blast.*—The advantages obtained by the use of the hot air blast are a saving of fuel and of limestone, and a large increase in the quantity smelted in a given time. That the method has these advantages is generally allowed: the degree in which they are considered to be attained, varies with the economy previously practised in those iron-works conducted on the old method, with the results of which we compare it; yet many think that these advantages are counterbalanced, by an equal deterioration in the quality of the iron produced. It is not to be doubted that such is the opinion of the consumer, since the hot blast pig iron brings a lower price in the market, by about eighteen shillings per ton.

* Beneath the main coal, for example, in the Auckland district, (county of Durham,) occurs a bed of fire clay, four feet thick, which might, in other circumstances, have contributed to give a workable value to the coal it adjoins.

The great defect charged on hot blast iron, whether in pig or in bar, is that its tenacity is not equal to that of cold blast iron. In addition to this the former loses on remelting in the cupola, an additional cwt. per ton.* That these defects, with the

* My friend Mr. Hartop, of the Elsecar iron works, a gentleman of long experience and great skill in the iron trade, but who may also be a little prejudiced, has furnished me with the following comparative statement of the cost of material, and the value of the product in the two processes:—

"With respect to the process of making iron with the hot air, I have come to the following general conclusions:—

	s.	d.
In favour of hot air.		
The saving in coal in the furnace is from 5 tons to 3, and not from 8 tons to 3, as often stated, per ton of iron made, 2 tons of coal at 5s.	10	0
In coker's wages, say	2	3
	12	3
Against the hot air.	s.	d.
Say 3 cwt. of raw ironstone used, (*extra*) now at 8s. 6d. per ton	1	3
Extra wear and tear, per ton of iron made	3	6
	4	9
Saved by the use of hot air per ton	7	6

But the deterioration in value in the market of iron so made, *is now* from 17s. 6d. to 20s. per ton, and respectable iron founders will not use it at any price.

It is said about *half as much more* iron can be produced from the furnace at which hot air is used, the saving in which will not, however, be more than 2s. 6d. per ton for the interest of building capital.

If, therefore, you add 2s. 6d. to 7s. 6d. = 10s., the saving is yet very far from the deteriorated value.

If you ask why iron so made, is sold for so much less in the market, the answer is its great weakness, and therefore its total unfitness for *most purposes*; its *greater loss* in melting in the cupola of 1 cwt. per ton, and much more than this in making it into bar iron. The iron founders also find very great irregularity in the contraction of castings when cooling, if made of hot blast iron; and the men at the cupola say it melts like burnt iron. Now burnt iron may be bought in the market at from 15s. to 30s. per ton, which is little more than one-third of the price of the most inferior pig, which is made with coke and cold blast."

If Mr. Hartop's opinion in regard to the comparative value and quality of the two kinds of iron be drawn from the relative strength of the Elsecar and Milton irons, the results of Mr. Fairburn shew, in so far as the specimens actually experimented upon are concerned, that his opinions are not without foundation. That they are sound in regard to *all* hot blast iron is at least doubtful.

exception of the last, are not constant, at least in amount, appears, I think, from the valuable experiments made by Mr. Fairburn and others, on the comparative strength of hot and cold blast iron from different localities:—

Blast.	Tensile, per sq. in.	Compressive, per sq. in.	Transverse. ratio.	To bear impt. ratio.
Carron iron, No. 2—hot	13892	98125	979·9	1038·9
cold	......	100631	1000·0	1000·0
Buffing iron, ...hot	13434	86397	925	965
Staffordshire, No. 1—cold	17466	93·366	1000	1000
Coed Talon, No. 2—hot	16·676	82·734	1014	1219
North Welsh, ...cold	18·855	81770	1000	1000
Devon, ...No. 3—hot	219107	145435	1409	2742
cold	......	......	1000	1000
Elsecar, cold blast, No. 1			809	858
Milton, hot blast,... No. 1			1000	1000

These results are sufficiently discordant to permit us to entertain a doubt whether hot blast iron must necessarily be of inferior quality. Were the differences always as striking as between the Elsecar and Milton irons, the question might almost be considered as decided; but when in other cases, as that of the Carron irons, the strength of the two varieties is nearly equal, we are justified in believing that, when very weak iron is made by the hot blast, some indispensable precautions are overlooked or neglected.

At all events, since the use of hot air confessedly shortens the process of manufacture, and causes a large saving of fuel, it ought not hastily to be condemned or abandoned, as if the process—an invention only of yesterday—had already reached its utmost perfection, or, as if the iron obtained by it could never become equal in quality to that prepared by an older method, which long experience has gradually and slowly improved. The example of other processes in the arts, defective, all of them, when first introduced, teaches us to look forward to the improvement of this one also, and justifies us in predicting that at no very distant period, iron of every quality may be manufactured by this quicker and cheaper method.

There is one source of inconvenience and uncertainty in the cold blast process, which appears to have a distant connection with the cause of the alleged bad qualities of the hot blast iron. It is familiar to every iron-smelter that the same proportions of the same materials, heated together in the same way and in the same furnace, will not ensure the production of iron of the same quality. After every precaution has been used, it is found impossible to secure a run of pig iron of the first quality for any given number of times in succession. The only apparent cause of these differences is a change in the temperature and hygrometric state of the atmosphere, and a consequent change in the temperature of the interior of the furnace—and the apparent remedy would be, the throwing into the furnace a current of air of invariable temperature.

In the hot blast, the temperature in the interior of the furnace is much higher than in the cold blast process—the whole mass of fused iron in the bottom of the furnace is maintained at this higher temperature, and it is finally run off into the sand in the same state. Now we know that the more rapidly the carbonaceous irons are cooled—whether in the form of cast iron or of steel—the more brittle or less tenacious they become; and as the velocity of cooling in hot bodies of the same kind, increases in a much higher ratio than the increase of temperature, it is obvious that the hot blast iron run off at so great a heat, must be in much less favourable circumstances, in so far as tenacity is concerned, than the cold blast iron. It *should be* so far inferior to it, as it has been exposed to the deteriorating consequences of a more rapid cooling from a higher temperature. If this cause really operate, the remedy for the inferior tenacity of the pig would be, to allow the metal to cool gradually, either in the smelting furnace or in a separate cupola, and to as low a temperature as is consistent with perfect fusion, previous to running it off. It may not be unworthy the attention of the iron master to test this supposition.

That the brittleness attributed to hot blast pig iron may be connected with the high temperature at which it is run out of the furnace, is rendered more probable by the known effect of the same cause on other metals. Thus Professor Johnson,* of Philadelphia, found the tenacity of a bar of tin to be much affected by the temperature at which it was cast.

Cast cool into a cold mould it sustained	6282 pds. per sq. in.		
—— hot, not red	5208	...	...
—— red hot into hot mould	5062	...	...

thus giving a diminution of tenacity to the amount of one-sixth, when the temperature of casting was raised a few† hundred degrees. Tin differs much in its properties from iron, yet there is such an analogy in the effects of rapid cooling upon both, as would sufficiently justify you in anticipating a beneficial result from the method of slow cooling above suggested.‡

Use of raw coal in smelting.—There is one result from the introduction of the hot blast into the smelting furnace, which cannot fail to obtain for it the good wishes of every one interested in the economy of our mineral resources, and ultimately to secure its adoption in many of our most extensive iron works. I allude to the means it furnishes for burning

* Journal of the Acad. of Nat. Sciences of Philadelphia.

† Tin melts at about 442° (F.), and a bar of iron becomes visible in day-light at 980° (F.)

‡ In regard to the bar iron, it is to be remarked, that the method of annealing may exercise an important influence on the tenacity of the two varieties. By an improper method of annealing, iron sometimes loses as much as 46 per cent. of its tensile strength. And though it may prove true that by the same method of treatment, bars prepared from hot and cold pig do not exhibit the same defects—it should be considered that the raw material prepared by methods so different may require different manipulations—may anneal under unlike circumstances, which ought to be carefully studied. For much interesting and important information on this and kindred subjects, I would refer you to the "*Report of the Franklin Institute, on the strength of materials for steam-boilers.*"—*Philadelphia*, 1837.

raw coal in the furnaces, and especially for introducing anthracite coal into general use and estimation.

No one who is acquainted with the enormous waste of combustible in the process of coking, can have failed to hope and wish that some means should be devised, for diminishing or wholly preventing so great a national loss. The average quantity of coke obtained from our English coals does not exceed one-half of the weight of coal employed. In some localities, as at Low Moor iron works, the produce is about 12 cwt. from every ton. The Welsh culm yields about 70 per cent of coke.*

This loss consists of the more volatile parts, which are partly burned and partly driven off by the heat. There can be no question that every portion of that which is volatilized, possesses a considerable heating power, which by proper arrangements might be made available for economical purposes. In the ordinary method of smelting, it is not impossible to use raw coal, but the loss is not diminished, the effect of a

* It is impossible to calculate precisely the loss of heating power which results from the process of coking. If we estimate the quantity of coal necessary for smelting one ton of pig iron at 5 tons, and allow the large additional quantity used in converting the pig into bar iron to stand against the saving effected in the manufacture of say 150 thousand tons by hot blast—then the coal actually coked for the iron furnaces will be very near 5 millions of tons. And if we reckon one-third for loss in coking, which will allow for the larger quantity obtained from the Welsh coals, the loss of heating material will be 1,666,000 tons a year.

It is calculated that 40,000 tons of coke are consumed by the locomotives which terminate at Birmingham alone. If 50,000 tons be used by all the other locomotives in the kingdom, the loss in making this coke will be 30,000 tons.

About one-half of the coal consumed in England is employed in our manufactories and steam-boats; some reckon it at little more than one-fourth, but the iron trade alone consumes this quantity. Let this half be twelve millions, deduct the 5,100,000 we have already accounted for, and suppose one-fourth of the remaining 6,900,000 to be coked for use in our foundries, converting, and other furnaces, and we have an additional loss equal to 575,000 tons, making in all an annual loss to the country of 2,271,000 tons of combustible material by mere dissipation in the process of coking. This estimate, however, must be received at its true value, since in the absence of correct data we can only *guess*.

ton of coal being no greater* than that of the coke prepared from it, and the inconveniences are sufficiently great to give a preference to the method of previous coking. If this great loss can not, by any new contrivance, be avoided, it is exceedingly desirable that some species of fuel should be introduced, containing less of this volatile portion, and attended consequently with less waste. Such a fuel is the anthracite or blind coal, of which large stores are to be found in Wales. The hot blast is likely to impart a new value to this coal, by introducing it into general employment.

In regard to fuel, there are three ways in which the hot blast is likely to effect a national saving.

a. By removing the inconveniences attendant on the use of raw coal in the furnace, it will save the expence of coking, and admit of the employment of coals not hitherto applicable to the purposes of smelting, because not possessed of the coking quality in sufficient perfection.

b. It is not unlikely that a portion of the saving, when coal is used in the hot blast, is due to the rapidity of the process. This will probably prevent the loss by volatilization, of so large a quantity of the combustible as uniformly takes place when coal is employed by the old process. Still, even by this method, much heating power must be dissipated, and therefore to the third method—

c. The use of anthracite coal—we must look for the most important national benefit likely to result from the new mode. The difficulty with which this coal is kindled and burned has hitherto prevented its general employment for industrial purposes. The high temperature induced by the hot blast overcomes this difficulty, and ensures an easy and perfect combustion. Little or no volatile matter is contained in stone coal, and no loss of heating power therefore can ensue from the

* Such is the experience at Low Moor, so celebrated for its first-class iron.

blast.* Suppose a pound of bituminous and one of anthracite coal to be each of heating power sufficient to evaporate one gallon of water, the latter in the furnace will produce its entire effect, whereas the former actually produces an effect equivalent only to the evaporation of half a gallon. The general use of anthracite coal, therefore, will save all this waste, and preserve the bituminous coal for use in processes where it is not so difficult to apply it economically.†

2°. *Abandonment of the refining process.*—Whatever shortens the process of a manufacture, must diminish the cost at which the marketable commodity can be produced. Such may be calculated upon as likely to be the effect of the omission of the refining process in some of the iron-works in Staffordshire. The refining process is usually the first step in the conversion of pig into bar iron. Two effects are generally supposed to result from it. It is supposed to remove certain impurities (especially phosphoric acid which exists in many of our ores) and to burn away a portion of the charcoal, which it is the principal object of the next step, the puddling process, entirely to remove. In so far as the mere removal of the carbon is concerned, it is obvious that this might be as well effected by a somewhat longer treatment in

* This is not strictly true of any of the Welsh stone coals, or anthracites; the least bituminous of which contains 7 or 8 per cent. of volatile matter. Very little of this however, it may be presumed, is lost in ordinary combustion. When coked of course there is a loss.

† I may here allude to a minor waste of combustible. The interior of the retorts in our gas-works gradually becomes coated with a thick layer of carbonaceous matter, which causes them to be burned through, and which remains in them when they are removed. In an iron-work at Monkwearmouth, in which these old retorts from London and elsewhere are re-melted, this cinder had accumulated so largely as to be employed for the building of walls for fields and enclosures, till a quantity of it was accidentally thrown into the cupola along with the iron, and was found to burn so well, and to be so durable in the fire, that it has ever since been employed as a valuable combustible. The cast-away portions have been carefully collected, and the old walls have disappeared in the devouring furnace. Many small wastes occasion a great national loss.

the puddling furnace; how far the presence of the impurities supposed to be removed by the refining would injure the quality of the iron thus obtained, is altogether a matter of experiment. The presence of phosphoric acid renders iron *cold* short, a property which the Staffordshire iron rarely exhibits, being generally *hot* short. The ore of that county, therefore, would appear to contain little of the phosphates of lime or of iron, and hence probably the reason why the refining of the iron has been successfully abandoned at the Chillington works. It is for the practical iron-masters of this county, to determine how far the same step can be safely omitted in the smelting of your ores; and whether by omitting it, an iron can be produced equal in toughness and general strength to the irons of Low Moor and other localities, which bring the highest price in the market.*

In the Chillington works the iron is run from the furnace into a long trough, perhaps 15 feet by 10, dug in the floor, and paved with iron or stone blocks. In this it forms a cake three or four inches thick, on which a stream of cold water is allowed to flow until it is perfectly cooled. It is then broken up easily, being white, brittle, and presenting the ordinary fracture and hardness of refined iron. This is afterwards submitted to the action of the puddling furnace in the usual way.†

It was natural to suppose that there could be little virtue in the mere cooling of the iron previous to the puddling, and that an identical result might be anticipated, while much fuel

* The iron trade has split into two branches—the one producing ordinary iron worth about £10.—the other a much superior iron worth £15. per ton.

† In regard to the quality of the iron manufactured by this process, Mr. Mushet stated lately (March 6th, 1838) in a paper read before the Institution of Civil Engineers, that he considered it "peculiarly adapted for railway purposes; that by omitting the refining process a greater mass of fibre can be produced than in any other manner; and that this fibre in consequence of the iron not being exposed to so severe a degree of decarbonization is stiffer and harder than that acquired by repeated heatings and rollings."—*Mining Review for April* 30, 1838.

would be saved, by transferring it at once in a state of fusion from the smelting to the puddling furnace. This was tried at Chillington, and found so successful, that a patent was obtained for the improvement, but one of those hindrances which have stifled many other inventions in their cradle, has for the present caused the method to be laid aside. It was found impossible to induce the workmen to act fairly by a process which they thought likely to effect a material abridgement in the time necessary to the manufacture of bar iron, and a consequent diminution in the demand for labour.

There is one inconvenience attendant upon the omission of the refining process, which has not yet been surmounted. The bottom of the puddling furnace consists of a thick plate of iron, on which is placed a quantity of the slag of the refining furnace, forming a durable bed on which the iron rests during the process of puddling. When refined iron is employed, this bed is found to increase in thickness, so that portions of it from time to time are removed, but when the hard unrefined iron above described is employed, the bed wastes away and allows the iron bottom to be *burned* and destroyed. No substitute has yet been found for the refinery slag in forming this bed, and, therefore, a small portion is still refined for the purpose of procuring the requisite supply of slag. A patent was some time ago obtained, I believe by Mr. Mushet, for a substitute, which is said, however, to have been only partially successful. How easy would it be for the iron trade of Staffordshire to procure a remedy for a difficulty such as this, by offering a reward so large, as to command the attention and secure the exertion of the highest scientific skill.

A few years ago a difficulty of a precisely similar kind occurred in the lead districts, in regard to the cupels employed for the extraction of the silver in the lead refining process. Mr. Stag, the skilful agent of the London Lead Company, proposed that the directors should offer a reward of £1000.,

for the discovery of a method of rendering the cupels more durable, showing them at the same time that the knowledge of such a method would prove a saving to them in their extensive works, of many thousands a year. This recommendation was not acted upon, because the discovery actually took place while the proposal was yet under consideration. We cannot doubt, however, that Mr. Stag's suggestion involves the only sure principle, by which in this country all such difficulties are to be overcome.

3°. *Resmelting of the ferruginous slags and cinders.*—The slags from the refining and puddling furnaces, as well as that squeezed out from the balls by the hammer, after they are removed from the latter furnace, contain a large quantity of iron, chiefly in combination with the siliceous and other matters existing in the raw pig, or derived from the fuel. The per centage of metal in each of these slags is almost always greater than that which is present in an equal weight of the ore* originally thrown into the smelting furnace. The loss of iron, therefore, if these slags be rejected, is equal at least to the waste of as many tons of native ore. Yet these slags have been rejected more or less from the very commencement of English iron smelting. Millions of tons have been thrown away in Staffordshire, millions probably are lying among the waste heaps at Low Moor, and millions more have been employed in mending the roads in various parts of the island.

Can no saving to *any* extent be introduced into this branch of the art? Many iron masters say not; and the opinion is very generally diffused among persons engaged in the trade, that no part of the slag can be re-melted along with the ore, without producing a perceptible deterioration in the quality of the iron obtained. Against this opinion, however justified by past experience, all analogy, and the history of every

* I refer of course to the clay iron ore occurring in our coal-fields.

branch of science, and every department of art bear testimony. Had the ore been higher in price this persuasion would long ago have vanished, and were a considerable scarcity now to arise, the faith of the most prejudiced would speedily be shaken. The stimulus to ingenuity, at present too small, would then be supplied, and efforts would be made on every hand to extract a marketable commodity from the slags now suffered to run to waste.

Improvements are making in the smelting of all other ores, and in almost every country, and must those of iron form a solitary exception? While the application of scientific principles, of new mechanical contrivances, and of a stricter economy of materials, are redeeming from waste the *rejectamenta* of the older furnaces, and enabling the smelter of other metals to work, with profit, ores formerly far too poor to repay the necessary expences;—while the improvements lately introduced in Cornwall, for example, give a marketable value to ores which produce only 3 or 4 per cent, of metal, and in some cases repay the smelter for extracting even smaller quantities;—while old lead heaps are cast into the furnace, ores of zinc and copper are regathered from the roads, and old copper slags remelted—are we patiently to look on in despair of rescuing our iron trade from the charge of extravagant waste? Can there be means of saving within the reach of the workers of other metals, and is there no hope for the smelters of iron? The progress of knowledge forbids us to cling pertinaciously to old opinions and processes, and to pronounce improvements to be impossible, because we cannot at once discover them.

The transition from charcoal to coke-iron—from the process of smelting with charcoal to that of smelting with coke—was as difficult and attended probably with as much private loss as any other improvement in the trade is likely to be.* Are difficulties, therefore, to deter us now?

* See Lardner's Cyclopædia. Manufactures in Metals, I., p. 31.

By the omission of the refining process, the production of the rich slag of the refining furnace is avoided, and the entire production of ferruginous slag is confined to that which flows from the puddling furnace, or is squeezed out of the metal when it is first brought under the hammer. So far there is a manifest saving. At Chillington the greater part of the slag thus produced is returned into the smelting furnace, mixed with raw ore in the proportion of one to seven, and this mixture, besides the saving attendant upon it, is said to correct the *red short* property exhibited by the Staffordshire iron, when manufactured from the unmixed ore. By many the iron is said to lose in *fibre* by the admission of slag or cinder into the smelting furnace; but every one who is desirous of husbanding the national resources must wish well to any attempt that promises to secure them from unnecessary waste; and will carefully exclude from his mind every prejudice which may tend to retard the progress of improvement, or to undervalue the results which have already attended its advance.

There are few things more interesting to one who is accustomed to watch the onward movement of natural and physical science, than to observe the evidence of progression which marks every process, and every part of every process, in a large manufactory like that at Chillington. New efforts at economy* are seen on every hand; and in the thousand ingenious contrivances, completed or on trial, to diminish the cost of production, is strikingly manifested the powerful stimulus of unceasing competition on increasing capital.

I have thus discussed at considerable length the most important alterations, by some considered as improvements, which have been recently introduced into a branch of manufacture in which the West Riding of Yorkshire is largely in-

* Among other economical applications at Chillington, is that of the *waste* heat from the puddling furnace to the production of steam for the engine that works the blast.

terested. I have entered more fully into the subject, because there are among you many iron masters, whose attention can not be too strongly drawn to the actual state of the art of smelting, nor too forcibly directed to those points in which the call for improvement is most imperative, and the means of improvement, apparently, most within your reach. The alleged amendments we have been examining are *all* confessedly imperfect—*all* only partially introduced—and *all* actually disputed. They are, therefore, proper subjects for the consideration of a Polytechnic Society, and it will be one of the duties of the enlightened members of your body, who are connected with the iron trade, to suggest to your committee those measures which it might be most proper to adopt—with the view of impartially testing the alleged improvements, and if found to deserve the name, of assisting in bringing them to perfection.

Natural argument against waste.—In what I have hitherto said, in regard to a wasteful expenditure of your resources, whether of coal or of ironstone, my reasonings have been founded on expediency only. I have drawn your attention solely to the practical benefits that would result to the nation, to the county, and to yourselves, by a strict economy of your mineral wealth—both by the miner who raises it, and by the manufacturer in whose works it is consumed. Will you permit me, before quitting the subject, to urge this economy upon you still further, by a reference to the general disposition of things throughout every department of nature.

In the organic and the inorganic worlds, the mutual relations of living and dead matter, and the changes undergone by material substances during the various operations of nature, all enforce upon us the important lesson—AVOID ALL WASTE. In the organic world we can discern no waste of animal or vegetable matter, living or dead. All plants, and nearly all parts of plants, are used for food by creatures whose nature is adapted to their several qualities. Insects live

upon the growing plant—different races at times on different parts—one insect preys upon another—the bird upon both. So of dead plants: appointed insects devour them—insect scavengers—while the excess of their numbers, which superabundant food might create, is kept down by the ravages of other tribes. In the sea also, as on land, the weed is devoured by the herbivorous mollusk—the latter by the carnivorous, and both by the polype. The polype falls a prey to the smaller carnivorous fish, and he again to the larger. Dead animals are devoured by other living creatures. There is no stage of decay at which they are not fitted for food to some, so that, while pestilential effluvia are prevented, no waste ever occurs. It is not till the wants of animated beings are supplied, that the residue is either dispersed in the air to fulfil other missions, or committed to the bosom of the soil as a store of nourishment for future plants.

In the inorganic world too, amid all the changes which matter undergoes, no waste occurs. Coal, wood, the fat of animals, all change and disappear when they are burned, but the matter of which they are composed only puts on new forms. Having in its former state performed one set of purposes in the economy of nature, it is borne by the winds of heaven to other fields of usefulness. The air we breathe is changed also and rendered unfit for supporting animal life, but it is then only prepared to minister to the growth of plants. The moment any portion of matter is liberated from control, it assumes new forms and exercises new functions. Every residue is worked up, every stray portion is put to use, and no atom is left for an instant unemployed.

In all this does not dumb nature distinctly converse with us? Does she not hold out her practice as a pattern to rational man? Does she not silently appeal to us, and seem to say—if the Deity can afford no waste, can you?—if HE manifest a decided aversion to wastefulness, should you run counter to his obvious will and example? You will, I am

sure, forgive me, Gentlemen, if, impressed by such considerations, I have appeared to urge upon you too strongly or too frequently, the necessity of economy in every department of your mineral labours.

III. *Condition of the working classes.*—The topics to which I have solicited your attention in the previous part of this lecture, have related either to the development of the resources of the district, or to the more immediate benefit of the owners and masters only. But there is another important and far more numerous class, equally interested in the economy of the coal-field, and whose happiness must be more or less affected by every discovery connected with your mineral riches, and by every improvement in the arts to which they have given birth. I allude to the working classes, who raise the raw material from the bowels of the earth, and afterwards bring it into the condition of a marketable commodity. It is true that whatever tends to the general benefit of the county, must in some measure add to the comforts of every branch of the population. But though they must be indirectly benefited by your exertions, still much remains to be done for the working classes solely and directly. As employers, which many of you are, the condition of the working classes demands your serious consideration. How much ignorance prevails among your miners! how much improvidence among the men in every workshop! How numerous are the opportunities you enjoy of adding to their comforts, and increasing their rational enjoyments;—by promoting cleanliness—by encouraging education—by diffusing useful knowledge—by establishing libraries, benefit societies, and societies for mutual relief and instruction! Above all, how beneficially might this society exert itself, in spreading sound views in regard to the true relation between master and servant,—by which both might be brought to see that their interests are not two and separate, but one and undivided—by which a harmonious union might be maintained between em-

ployer and employed; putting an end for ever to combinations on either side, and the numerous train of miseries by which they are uniformly attended. How important too, that the progress of improvement should not be arrested by the opposition of the operative. The blinded spirit which led the southern labourer to destroy the thrashing-machine, and the weaver of the midland counties to break up the stocking-frames, still lingers in the workshops of the north: how much more rapidly would the arts progress, could you completely exorcise it!*

The opportunity you will enjoy for collecting important statistical details must not be passed by. Well digested tables of *economical statistics* will throw a flood of light on the actual state of your manufacturing and mining industry, and prove a powerful auxiliary in directing your efforts to those objects, from which the most immediate benefits are likely to result. Similar tables of *medical statistics*, embracing such

* The management of large bodies of workmen is a subject of great importance. It is an art of great delicacy, which most people think very easy to be acquired, and yet which very few persons ever thoroughly attain. The first object should be to instruct them, so that when you appeal to their reason you may be certain of being understood. A proper mixture of firmness with kindly feeling will then maintain both respect and subordination.

In the management of the London Lead Company's affairs in Teesdale, Mr. Stag, whose skill is so highly appreciated, among other regulations has long adopted the following,—

1°. Never to pay exorbitant prices, whatever the times may be; but

2°. To keep the men always employed at moderate wages, and in the worst of times.

3°. With this view, to reject no ore so long as there is not a clear loss in working it—so long as it will pay the workman's wages.

4°. To secure a provision to every man as soon as he is disabled.

5°. To take back no workman who once leaves the company's employment.

The object of all these regulations is very apparent, though in less remote districts and by a less powerful company, they could not all be enforced.

For many valuable suggestions and details, connected with the management of workmen in Cornwall, and with the economy of mines in general, I would refer you to an interesting lecture by Mr John Taylor, which is very fully reported in the *Mining Review for December*, 1837.

details as can be tabulated, in regard to the prevailing diseases in each locality, and especially attendant on the practice of each branch of art, will suggest to you various remedial measures, by which the liability of your workmen to special diseases may be lessened, the most efficient remedies provided when disease has been contracted, or the most soothing palliatives when fatal maladies prove inseparably connected with certain laborious employments.*

In your enquiries on these and kindred subjects, you will be aided by the willing co-operation, and stimulated by the example, of the Statistical Society of London, whose published schemes and lists of queries, are of incalculable value to local institutions.

Means of transport.—The means of transport form an important object of consideration to the national economist. I know not, however, how far the consideration of these means,

* The dry grinders of Sheffield are in this condition, but they set compassion at defiance, by refusing to employ those means of safety which have already been put within their power. Not so the intelligent and laborious, but ill-fated race of men who work in our lead mines. The last ten years of their lives are generally more or less embittered by disease of the chest, which the medical men do not comprehend, and for which medicine knows no cure. It is melancholy to see men who ought to be in the prime of their days, already incapacitated for work in the mines—lingering still for years in slow decay before their strength becomes utterly exhausted. In Cornwall, the affection of the chest is attributed to the exertion of climbing by ladders from the great depths of the copper mines,—and it is expected that by bringing up the workmen by the shafts, as in the coal mines, the evil may be overcome. In the lead districts this cause does not exist, and yet a similar disease is there almost an epidemic among the miners. It is attributed by the workmen themselves, with what degree of correctness it is impossible to say, to the evil effect of driving dead work—levels intended to open up new ground, or to connect different spots in the same mine. The ventilation in such places is necessarily very imperfect, and the smoke of the gunpowder employed in blasting, renders the air still more unwholesome. It is not unlikely that the constant presence of metallic particles in the atmosphere of the mine, may also have its effect on the organs of respiration—if indeed they are really the seat of disease.

How would he entitle himself to the blessings of these industrious and instructed races of men, who should discover the seat, nature, and source of this disease, and provide for it even a probable remedy!

apart from their connection with the supply of minerals to your manufactures, and the conveying to market your own immediate produce, may be esteemed by you as a legitimate object for a Polytechnic Society; but as I conceive your great aim is, in every possible way, to promote the prosperity of the section of the county in which your lot is cast, and as increased facilities for transport, and diminution of cost, are fundamental elements in local prosperity, you will be unwilling, I think, to pronounce that they shall occupy no share in your deliberations. If so, the establishment of railways, and the numberless questions and exciting speculations, with which, in the present day, they are connected—and especially the means of opening up communications of this kind with the more remote parts of the West Riding, by which the treasures of each section may become, as it were, part of the inheritance of the other—may be expected at times to vary the usual character of your discussions.

I have thus, Gentlemen, sketched a brief outline of the numerous questions, almost all of them of a practical bearing, which you may be called upon, at one time or another, to consider at the meetings of your Society. I have endeavoured to place before you, not only the number and nature of the subjects you may be called upon to discuss, but the public and private benefits also, which may be expected to flow from your exertions. I have only, however, opened the mine, which it remains for you to work: I have won the coal, which you will cheerfully and laboriously dig.

Means of attaining the objects of the Society.—There remains now only one other topic to be considered. In what way can your objects be best attained? Your safest guide on this subject will be, the example set before you by the most ably conducted and most prosperous societies in our own, and in foreign countries.

1°. Your public meetings are the first, and may possibly prove the most efficient, means you can employ. A calm

and temperate discussion of the questions brought before you, in the communications of your members, will gradually enlarge your mutual information, remove unfounded prejudices, and lead to the adoption of practical improvements—the propriety of which, the arguments of the individual author of the paper might have failed, alone, to establish to the general satisfaction. One end, also, you are sure to gain by your meetings. You will learn mutually to appreciate and respect the information possessed by each other, and will become willing to impart the little you individually know, that you may add to your stock the knowledge of all. Mutual jealousies, if any exist, will thus die away amid your amicable scientific discussions; and while you thus increase in private knowledge, and in kindly feeling towards the Society, its objects, and its members,—you will find, I trust, in the advancement of the general prosperity of the county in which you reside, the most certain prospect, as well as the surest guarantee, for your individual success in life.

2°. The institution of classes is another method by which, when the objects of a society are numerous, it has been generally considered that they may be more effectually attained. Those which I have recommended to your notice may be arranged under the several heads of—*theoretical geology*,—*engineering*—construction and duty of machines,—*practical mining*—the coal-trade,—*practical smelting*—the iron-trade, and *statistics*. You might with advantage institute a class or committee for each of these departments, giving a place in one or other to all your members, if possible, but especially to such as either professionally, or from inclination, are attached to particular lines of pursuit.

From each of these classes you should require a half-yearly report, taking two at each of your quarterly meetings. These reports should embrace not only what may have been effected by your own members, but also the most important discoveries and improvements, recently proposed or introduced, by

other persons. Thus, not only would the several committees be compelled to make themselves acquainted with the general progress of their departments, but the entire society would be kept up to the actual state of practical science, and would have an opportunity of discussing the merits of every new suggestion.

The annual address of your president or secretary would give you a general view of the united labours of all the sections.

Some of you may think this subdivision too great, but it would be attended with all those results, which, in the arts, are known to follow from the division of labour. Each class or section would have a definite sphere of exertion; and by being confined to a limited district, would be more likely to cultivate it well, and to suffer no corner to be neglected. You would also be able to secure for each, the zeal and activity of one or two industrious men, anxious to work if you assign them a definite object, but whose energy would diffuse itself generally, and run to waste, if allowed to expatiate at will over every part of your field of enquiry. The talent and industry of your members must, like steam, be confined and directed: left to itself, it will soon cool down or be wholly dissipated.

3°. The publication of your proceedings is a third way by which you may advance towards the objects you contemplate. It is a laudable desire among those who labour in science or in art, that the results of their exertions should be widely circulated, that while the greatest possible good may thus be effected, they themselves may receive that meed of applause to which they are justly entitled. The more you can encourage your members by such fair means, the more zealously will they co-operate in furthering your views. I do not suggest that you should confine yourselves to the publication of expensive transactions, which could appear but seldom; but that frequent abstracts of your proceedings should appear,

either in a separate form, or in some of the prints or journals. These would more generally attract the public attention—diffuse more widely the persuasion of your ability to do good—enlist the public sympathy in your behalf—encourage the wavering or indolent among yourselves, and stimulate to further exertions, those whom judicious praise would urge onward to renewed and strenuous application.

4°. I shall mention only one other of the various methods that may occur to you, of attaining more fully and more certainly, some of the more special ends you have in view. You are sufficiently aware of the necessity of holding out inducements to the performance of a piece of work—such as the labourer may consider, in some measure commensurate to the task imposed upon him. The most learned bodies have considered it not inexpedient to offer premiums for specific researches, in regard to which men are not likely to be sufficiently stimulated, even by the applause of those who occupy the highest seats in science—and the most brilliant and useful discoveries have not unfrequently been the result. New subjects of practical difficulty, such as require much labour, thought, and investigation—or which involve much expense of time or money—are precisely of that class which you would not expect to be taken up and prosecuted by an individual, from the mere thirst for knowledge. The sympathy and encouragement of the prosecutors of pure science would not attend him in his devotion to such enquiries—if he gained no money by them, he would be certain of earning little reputation.

In such cases, however, the judicious stimulus of a handsome premium would soon bring labourers into the field. The honour of gaining a *prize* would be superadded to that of overcoming a difficulty; and you would enlist in your cause individuals, whom the private offer of a larger sum, would not have induced to turn their attention to the subject.

It is not to be supposed that your funds will soon enable